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Abstract

We develop an empirical model of inflation in Tanzania for the decade from 2001, estimating 'multiple determinant' single-equation models for month-on-month headline inflation and its principal components (food, energy and core inflation). Our results suggest that while supply-side factors, including yield variability and international price arbitrage pressures, play a major role in determining domestic food and fuel inflation (which together account for almost 60 percent of the total CPI basket), demand-side factors amenable to policy intervention by the monetary authorities anchor core inflation. The models are constructed around high frequency and timely data allowing this work to support the development of an inflation-forecasting capability by the Bank of Tanzania. The paper concludes by discussing a number of concerns about data quality and identifying areas for further research required to achieve this objective.

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1. Introduction

Addressing the recent sharp rise in inflation has become a central macroeconomic policy concern in Tanzania, as it has across East Africa. For the first decade following the deep liberalization measures of the mid-1990s, the economy enjoyed strong output growth and low and stable headline inflation that remained close to the authorities' indicative target of 5 percent per annum.[1] Since the onset of the global financial crisis, however, the macroeconomic environment has become much more volatile. Growth has fluctuated and year-on-year headline inflation edged above 10 percent in mid-2008. It dropped back to low single digits in 2009 and 2010, before rising sharply again in the third quarter of 2010, reaching close to 20 percent per annum in the third quarter of 2011 (**Figure 1**). At the time of writing it is unclear whether the recent surge in inflation has reached its peak and will turn down in the first half of 2012 or whether further increases are likely. What is reasonably certain, however, is that the outlook for both the global and domestic economy suggests a rapid return to the benign inflationary environment of the early 2000s is unlikely.

This more volatile environment makes the central bank's decisions both more difficult and more constrained. Some of the pick-up in inflation and inflation volatility clearly reflects developments in the global economy -- most obviously the rise in global food and fuels prices, in 2008 and again in 2011, to levels not seen since the mid-1970s. Theory suggests the initial inflationary effects of these external price shocks should be accommodated and that monetary policy should limit itself to making sure that the ensuing second-round pressures on wages and price are resisted lest they become embedded in domestic inflation expectations. A central question, however, is how much of the current surge in inflation really is due to these external factors and how much is actually a reflection of domestic factors including a fiscal and monetary stance that is too loose given aggregate supply. If these latter factors are important, the authorities should be seeking to tighten monetary policy more aggressively at the margin, despite global market conditions.

It is not the purpose of this paper to advise on these immediate policy questions. Rather its contribution is to strengthen the Bank of Tanzania's capacity to do so by contributing to the development of a coherent empirical framework for the analysis of inflationary trends in the economy. Specifically, we seek to develop an econometric model of the inflation process in Tanzania, one that both identifies the principal structural determinants of inflation in the economy and that ultimately provides a basis for developing operational inflation forecasting models within the Bank of Tanzania that are capable of guiding the policy decisions of the Monetary Policy Committee.[2]

The remainder of the paper consists of three main sections. In Section 2 we document in more detail the recent history of inflation in Tanzania. The key feature of this analysis is the dominant role

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[1] As discussed elsewhere in the paper, there are a number of controversies surrounding the measurement of inflation throughout this period, but particularly before 2001. We evade some of these by focusing our analysis on the period from January 2002, using the CPI series that had been revised back to that date following an IMF mission to Tanzania in 2006 (see Appendix I). On this basis, mean headline inflation from January 2002 to the eve of the global financial crisis in April 2008 averaged 5.75% per annum and did not exceed 10% per annum through the period.

[2] A companion paper to this one, examining inflation forecasting, will be produced in early 2012.

played by food prices and the cost of moving food from producer to consumer. Although its share of the consumption basket has fallen from around 70 percent in the early 1990s, food still accounts for close to 50 percent of total consumption,[3] by far the single largest component, with energy and transport costs accounting for a further 9 percent each. As of November 2011, year-on-year inflation in the food and energy sub-indices reached 26.1% and 39.2% respectively.[4]

In Section 3 we develop a model of the three components of headline inflation, namely food, energy and core inflation, where the latter is the residual item. The empirical model is in the tradition popularized by Hendry (2001) and others who model inflation in an open economy – in Hendry's case, the UK -- as anchored in the long-run by both demand-side or monetary factors on the one hand and supply-side and open economy price arbitrage factors on the other.[5] Typically, these models are estimated under various identifying restrictions imposed on an underlying structural vector error correction model (VECM) defined around cointegration relations that reflect these inflation anchors. Often, including in Hendry (2001), the inflation equation is estimated as a single equation derived from Johansen's (1992) weak exogeneity restrictions on the underlying VECM. We adopt the same approach here. Section 4 of the paper discusses the estimation results and the final section, Section 5 concludes by making some preliminary observations about developing an operational framework for short-term forecasting of inflation.

2. Inflation: stylized facts

A simple analytical framework

A conventional starting point for the analysis of inflation in small open economies such as Tanzania is the Salter Swan two-sector framework, in which the overall (headline) price index is defined as a geometrically-weighted average of the price of tradable (T) and non-tradable (N) goods such that $P_t = P_{Tt}^{\alpha} P_{Nt}^{1-\alpha}$ where the exponents are expenditure shares and t denotes time. Taking logs and differentiating with respect to time, headline inflation can be approximated as a weighted average of the sectoral inflation rates,

$$\pi_t = \alpha\pi_t^T + (1-\alpha)\pi_t^N.$$

[3] Food accounted for 71.2% of total consumption in the 1991/92 Tanzania Household Budget Survey (HBS) and 55.9% in the 2001/02 HBS. The food share in the 2007 HBS is 44.3%. However direct comparisons over time are imperfect since the detailed classification of the consumption basket has changed over time. For example, the new 2007 HBS, which is based on the UN's Classification of Individual Consumption by Purpose (COICOP), now includes non-alcoholic beverages in the 'food share' but excludes food consumed outside the home in hotels and restaurants. The current CPI, published for the first time in September 2010, defines a total food aggregate by combining food, including food eaten outside the home, and drinks (alcoholic and non-alcoholic). This accounts for 51 percent to total CPI.

[4] Source: NBS Bulletin November 2011.

[5] We are not aware of any comparable work for Tanzania but variants of this class of 'multiple determinants' model has been estimated for a number of countries in Sub-Saharan Africa in the last decade or so, including: for Mozambique by Ubide (1997); for Mali and Chad by Diouf (2007) and Kinda (2011) respectively; for Kenya by Durevall and Ndung'u (2001); and by Loening, Durevall and Birru (2009) for Ethiopia. An important exception is Barnichon and Peiris (2008) who employ panel cointegration methods to compute identify output and aggregate demand gaps which then feed into a conventional expectations-augmented Phillips curve.

By the small-country price-taking assumption, tradable prices are defined as $P_{Tt} = E_t(1 + \tau_t)P^*_{Tt}$, where P^*_T denotes the world price of tradables, E is the suitably-defined nominal exchange rate and τ denotes tariff or other relevant price wedges, including transport costs. If the latter are constant over time, and letting $\hat{E}_t$ denote the depreciation of the nominal effective exchange rate, the inflation rate for tradable goods is given by the relevant 'world' inflation rate for tradables and the depreciation of the appropriate trade-weighted exchange rate

$$\pi^T_t = \hat{E}_t + \pi^{*T}_t.$$

Inflation in non-tradables, on the other hand, is determined by the balance of excess supply and demand in the domestic economy. On the demand side it is conventional to focus on the determinants of (excess) aggregate nominal demand; on the supply side, a range of factors are adduced, the most important being the transmission of climatic variation to agricultural output and the pass-through of the price of (tradable) inputs such as energy prices.

To derive an empirical model of inflation that accurately matches the data for Tanzania, we embed this analytical distinction between inflation in tradable and non-tradable prices within a sectoral decomposition of headline inflation between three sub-indices: for food, energy, and core prices (the residual item) such that,

(1) $$P_t = P^{\beta}_{Ft} P^{\gamma}_{Et} P^{1-\beta-\gamma}_{Ct},$$

where F, E and C denote food, energy and core prices and β and γ are the weights of food and energy in the consumption basket. Headline inflation can then be written as a weighted average of the sectoral inflation rates,

(2) $$\pi_t = \beta\pi^F_t + \gamma\pi^E_t(1 - \beta - \gamma)\pi^C_t.$$

All three sub-indices in turn can, in principle, be further decomposed into tradable and non-tradable components.

In what follows we estimate (2) and its separate sub-components for the period from January 2002 to July 2011, but without imposing the restrictions across the sub-components implied by the weights. Ideally we would base our analysis on a much longer time series but for reasons of measurement error, discussed in detail in Appendix I, we felt it was unwise to use the price data before 2002. Indeed, there may well still be some quite serious measurement errors in the data we do use, a factor that the Bank may need to consider as it develops its inflation forecasting methodology. Our strategy for addressing such problems is discussed in the paper with some further details presented in Appendix II. Before turning to the econometric analysis, however, we present the basic features of the recent inflation experience in Tanzania.

Headline Inflation and its components: 2002 - 2011

Table 1 and **Figure 2** summarize year-on-year inflation rates of the revised CPI and its food and non-food components from January 2002 to June 2011.[6] Until around 2005 headline inflation was

[6] Price indices are normalized so that 2005m12 = 1. Our econometric analysis works with month-on-month growth in the log price indices, in other words monthly inflation. To better understand the underlying patterns

extremely stable around the policy target of 5 percent, after which it begins to trend upwards through to late 2009. Headline inflation fell until late 2010 since when it has risen again very sharply.

The stability of headline inflation over the early period is surprising given the volatility of the underlying food and non-food components, but as Figure 2 shows there was a systematic tendency for food and non-food indices to move in opposite directions over much of the sample. In particular, until 2010 non-food inflation rate tended to fall sharply when there was a spike in food inflation, most noticeably in 2003 and again from early 2008 to late 2009. So marked was this tendency that in 2003-04 non-food inflation was negative, meaning that the price *levels* of non-food items were falling in absolute terms on average. This powerful negative correlation between food and non-food prices is both striking and unusual. For example, 'structuralist' theories of inflation would suggest a positive correlation between food and non-food prices if urban workers seek higher nominal wages in response to increased food costs. Similarly, if higher food prices draw the fiscal authorities into budgetary measures aimed at mitigating the impact on households, inflationary pressures may emerge through pressures for monetary financing. A negative correlation may, however, plausibly emerge in a closed economy (or one where the stabilizing effects of international trade in food are weak) where a low price elasticity of demand for food and fixed nominal incomes means that rising food prices lead to an increased share of total expenditure allocated to food which, in turn, is transmitted as a negative demand shock onto non-food prices. This interpretation has gained some support amongst policymakers and analysts in Tanzania and, indeed as we show later, there are traces of these effects in the data. But it may also be a combination of coincidence and an artefact of data collection methods employed by NBS in the early part of the decade. Indeed, as Figure 2 shows, this headline inflation-stabilizing behavior has disappeared since mid-2010 and the correlation reversed: for the last year, food, non-food and headline prices have all moved closely together in the same direction.[7]

The reason for this change in correlation is made clear in **Figure 3** which decomposes non-food prices into an energy component, consisting of the sub-index for fuel, power, water and transport, and a core component consisting of all other non-food items. Doing so decisively moderates the food/non-food pattern observed in Figure 2. Core inflation continues to display a substantial degree of downward flexibility in 2003-04, but after 2008 there is little tendency for it to move in the opposite direction to food inflation. Since 2008, it has been the energy component – principally influenced by the global financial crisis and its impact on oil prices – that has accounted for the movements in non-food prices seen in Figure 2.

Before leaving this section it is useful to note that the overall price index in (1) can be re-written as $P_t = P_{Ct}\tau_{Ft}^{\alpha}\tau_{Et}^{\beta}$ where $\tau_{Ft} = P_{Ft}/P_{Ct}$ and $\tau_{Et} = P_{Et}/P_{Ct}$ are the real prices of food and energy relative to core prices, respectively. Taking logs, headline prices can then be written as

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in the data, however, the discussion in this section is framed in terms of annual inflation rates, in other words the year-on-year log differences in prices. Hence the inflation rate is calculated as $100^*[\ln(P_t) - \ln(P_{t-12})]$).

[7] It has been argued by some that the negative correlation in the early part of the decade may in fact have been an artefact of the data compilation procedures used by NBS in the early 2000s. We discuss this possibility in Appendix I.

(3) $$p_t = p_t^C + \alpha log\tau_t^F + \beta log\tau_t^E.$$

Normalizing relative prices to 1, (3) states that overall price level will deviate from core prices only by shocks to real food and real energy prices. This representation of headline inflation provides a useful link with contemporary, New Keynesian, views on monetary policy in open economies which sees the objective of monetary policy as influencing 'sticky' prices to bring the economy as close as possible to the notional output and consumption path that would be followed if all prices were fully flexible (see, for example, Woodford, 2003). Hence monetary policy should target only those prices over which it has leverage, namely core prices, and accommodate movements in non-core inflation, at least up to the point that non-core inflation feeds through onto core inflation. By this definition, non-core prices are determined by supply-side factors or world market conditions: as such they should be excluded from the inflation target.

This New Keynesian view typically assumes that while real price movements may be large they are stationary processes so that headline and core prices will be cointegrated. As **Figure 4a** shows, however, this has not been the case in Tanzania in the last decade or so. Core and headline prices follow very different trends particularly over the early part of the sample and are decisively not cointegrated[8] implying that one or other of the relative prices are non-stationary over the sample. In fact, as shown in **Figure 4b,** both are non-stationary. Relative prices for food and energy both rose by nearly 20 percent between 2001 and 2006, and then remained at this new level before diverging in the latter half of 2008. In the empirical estimates reported below we include trend terms to control for the non-stationarity of relative prices. Whilst this helps us derive a plausible econometric model for the data at hand, it is far from ideal: it suggests that the measurement errors in the price data may run deeper than we might have thought (see Appendix II).

3. Estimation Strategy

The aim of our empirical approach is to reflect these different transmission channels. The models we estimate follow in a tradition developed by Dennis Sargan (1964) and latterly reprised by Hendry (2001) in his analysis of UK inflation and, more recently, by Loening et al (2009) in their work on Ethiopia. The approach is to embed a set of 'single cause' models of inflation within a generalized framework in which inflationary pressures emerge from the deviation from equilibrium in a number of different markets. In Hendry's application to long-run inflation in the UK from the 1870s to the end of the 20th century, the sources of inflation were: disequilibrium in the goods market (proxied by a measure of the output gap); excess demand in the money market; price pass-through effects from world markets; and cost-push effects operating through the domestic labour market.

For a low-income agricultural economy such as Tanzania (and as shown by Loening et al for Ethiopia) this structure needs to be modified. Hence we retain both the excess aggregate demand channel operating through the money market and the pass-through from world prices for food, fuel and manufactured goods. We do not model cost-push factors in the labour market, however. In part

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[8] This is confirmed using a standard Phillips-Perron unit root test on the residuals from the regression of headline on core inflation. The test statistics against the null of no cointegration is -2.488 against a critical value of -3.398.

this is a practical matter as consistent time-series data on wages and employment do not exist even for the public sector, but it also reflects anecdotal evidence suggesting that cost-push pressures emanating from the labour market are not powerful drivers of inflation in Tanzania.

The principal difference of our approach is how we model the supply side of the goods market. In their work on the drivers of inflation across a panel of countries in Sub-Saharan Africa, Barinchon and Peiris (2008) estimate the aggregate output gap as the deviation of actual output from an estimated aggregate production function. This approach is impractical in the current setting as sufficiently reliable factor market data required to estimate aggregate or sectoral production functions are not available for Tanzania, nor are real output data available at high frequencies. A quarterly real GDP series has been published since the mid-2000s but there are sufficiently serious concerns about the seasonality of this series to counsel against its use. We are therefore obliged to adopt an alternative approach. Following Loening *et al* (2009) we focus exclusively on agricultural output, assuming implicitly that that the non-food output gap is essentially demand-determined. Loening *et al* (2009) derive the agricultural output gap from a Hodrick-Prescott decomposition of actual agricultural output interpolated from an annual to monthly frequency. Given our concerns about the agricultural output data for Tanzania, we favour using a proxy for variations in agricultural output based on deviations of rainfall from its long-run seasonal mean in the principal food-producing districts of the country. We discuss the construction of this proxy in more detail later.

Ideally we would estimate a fully-specified structural system of equations defined in terms of inflation (and its components) and the other relevant endogenous determinants such as money, output, the exchange rate and domestic interest rates. Since we are working with a short data set, we have doubts about the robustness of such a system of equations. We therefore adopt a two-stage, single-equation approach, modeling headline inflation and its components as stationary processes that depend on their own past values, on short-term inflation determinants and lagged deviations from our set of pre-estimated long-run inflation anchors. In the light of the previous discussion these anchors consist of: world price arbitrage conditions for food and fuel; the 'natural rate' equilibrium in agricultural output; and money market equilibrium.

Our inflation equations therefore take the following error correction form

$$\begin{aligned}\Delta lnp_t^i = \beta_0 + \sum_i \sum_{j=1}^{k} \beta_j^i \Delta lnp_{t-j}^i + \sum_{j=1}^{k} \mathbf{\Gamma} Z_{t-j} + \alpha_1^i (m - \widehat{m})_{t-l} + \alpha_2^i (e^f - \hat{e}^f)_{t-m} \\ + \alpha_3^i (e^e - \hat{e}^e)_{t-n} + \alpha_4^i (e^c - \hat{e}^c)_{t-p} + \alpha_5^i (y^a - \hat{y}^a)_{t-q} + \sum_{s=1}^{11} \phi_s D_t^s \\ + \varepsilon_t\end{aligned} \quad (4)$$

where Δlnp_t^i is (12 times) the month-on-month change in the log of price index i where $i = \{headline, food, energy, core\}$. The deviations from long-run anchors are: $(m - \widehat{m})$, the deviation of real money from its equilibrium value; $(e^f - \hat{e}^f)$, $(e^e - \hat{e}^e)$ and $(e^c - \hat{e}^c)$ the deviations of domestic food, energy and core prices from their relative PPP values respectively; and $(y^a - \hat{y}^a)$, a measure of 'excess supply' in agriculture. The parameter vector $\boldsymbol{\alpha^i} = (\alpha_1^i \dots \alpha_5^i)'$ denotes the feedback effects from the long-run price anchors onto the relevant inflation rates. These long run effects are defined such that we expect $\alpha_1^i \geq 0$ for all *i*. For the coefficients

α_2^i, α_3^i *and* α_4^i we expect own effects to be negative and cross effects positive. Thus for example we would expect $\alpha_2^i < 0$ and α_3^i *and* $\alpha_4^i \geq 0$ when *i=food.* In other words, when the domestic food price exceed the exchange rate-adjusted world price, domestic food price inflation will fall to eliminate the disequilibrium but excess energy and core prices will, other things equal, increase food inflation. Likewise for energy and core prices. The vector ***Z*** consists of other exogenous short-run inflation determinants including a small number of dummy variables introduced to pick up measurement changes in the price indices. All elements of **Z** are either stationary or transformed to be so. Unit root tests are reported in Table A2 and full details of the construction of variables are provided in Table A3.

Before turning to the estimation results we consider each of the long-run anchors in more detail.

Monetary equilibrium

The characterization of the money market equilibrium is taken directly from our earlier work on the demand for money in Tanzania (Adam *et al*, 2010) in which we estimated an error correction equation for real money of the following form

(5) $$\Delta m_t = \beta_0 + \beta_1 \Delta m_{t-1} - \alpha[m_{t-1} - \delta_1 y_{t-1} - \delta_2 \boldsymbol{r}'_{\boldsymbol{t-1}}] + \beta_2 \Delta y_t + \beta_3 \Delta y_{t-1} + \beta_4 \Delta \boldsymbol{r}'_{\boldsymbol{t}} + \beta_4 \Delta \boldsymbol{r}'_{\boldsymbol{t-1}} + +\varepsilon_t$$

where m_t is log real M2, y_t is log of real GDP; and $\boldsymbol{r}'_{\boldsymbol{t}}$ a vector of variables measuring the opportunity cost of holding broad money plus a measure of the structural transformation of the economy,[9] where for simplicity of exposition we have imposed a lag order of *p* = 1. The vector $X_t = \{m, t, \boldsymbol{r}'\}' \sim \mathrm{I}(1)$ so that under cointegration, the term in square brackets measures the deviation of real money balances from their estimated equilibrium. In our work on money demand we restricted our attention to the adjustment of real money demand to money market disequilibrium. However, since the change in real M2 is given by $\Delta m_t = \Delta \log M_t - \Delta \log P_t$, we can rewrite the error correct term as $[logM_{t-1} - logP_{t-1} - \delta_1 y_{t-1} - \delta_2 \boldsymbol{r}'_{\boldsymbol{t-1}}]$ which makes it clear there are in fact four candidates for error-correcting behavior in response to money market disequilibrium: changes in nominal money supply ($\Delta \log M$), real GDP ($\Delta \log y$), opportunity costs($\Delta \boldsymbol{r}'$), or prices ($\Delta \log P_t$), where the latter is a measure of headline inflation. Here we focus attention on the extent to which excess money growth feeds back onto inflation.[10] The estimated error-correction term used in our inflation equations takes the form

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[9] This variable, which we refer to as the 'monetary intensity index' is a measure of the extent to which with structural change and liberalization a greater share of economic activity has become monetized.

[10] This re-interpretation entails 'inverting' the money demand equation to derive a price equation. As Ericsson and Irons (1994) show, this inversion is generally invalid in a single-equation setting. Here, however, we can think of the inflation equation as representing one of the row elements of a generalized VECM representation of the form $\Delta X_t = \sum_{k=1}^{p} \Gamma \Delta X_{t-k} + \Pi X_{t-1} + \Phi D_t + \varepsilon_t$ where $X_t = (logM_t, logP_t, y_t, \boldsymbol{r}'_{\boldsymbol{t}})'$ is the vector of I(1) stochastic variables and D_t a vector of deterministic factors (trends, seasonal factors etc) and $\Pi = \alpha\beta'$ the reduced-rank parameter vector defining the cointegrating combinations between the I(1) variables (β' vector) and their feedback on the dynamic equations of the system. If the cointegrating rank is 1 and the cointegrating vector, β' admits an interpretation as a money market equilibrium, the feedback coefficient α_2 represents the feedback from money market equilibrium to inflation.

(5') $$[M_t + P_t - 1.02y_t - 0.08s_t + 0.34\pi_t + 0.27\hat{e}_t - 0.017(i_t^{TB} - i_t^{D})] = z_t \sim I(0)$$

where y is real GDP, s the index of monetization, π inflation, $\hat{e}$ the depreciation of the nominal exchange rate and $(i_t^{TB} - i_t^{D})$ the spread between the opportunity cost of money and the weighted interest rate on deposits.[11]

Notice that using the definition of velocity of circulation, $v_t = y_t - m_t$, we can represent (5) as a velocity equation

(6) $$\Delta v_t = -\beta_0 + \beta_1 \Delta v_{t-1} - \alpha[v_{t-1} - (1-\delta_1)y_{t-1} + \delta_2 \boldsymbol{r}'_{\boldsymbol{t-1}}] + (1-\beta_2)\Delta y_t - (\beta_1 + \beta_3)\Delta y_{t-1} - \beta_4 \Delta \boldsymbol{r}'_{\boldsymbol{t}} - \beta_5 \Delta \boldsymbol{r}'_{\boldsymbol{t-1}} - \varepsilon_t$$

where the term in square brackets represents the deviation of *velocity* from its equilibrium value. We can use this observation to generate an alternative measure of money market equilibrium as the deviation of an *ex post* measure of velocity from its long-run trend

(7) $$v_t = v_t^{HP} + \varepsilon_t^{v}$$

where the trend, v_t^{HP}, is estimated using a standard Hodrick- Prescott or other filter. This proxy measure has the advantage that since it does not require full re-estimation of the demand for money it is extremely easy to compute in real time. The downside, of course, is that it does not allow velocity to respond endogenously to shifts in the opportunity cost of holding money (or in shifts to the income elasticity of the demand for money) which may be important at times of volatility. Over short horizons, however, such limitations may not be too serious. It should be noted, though, that the money demand model is estimated on quarterly data – and even then we have interpolated GDP from annual to quarterly frequency: using either the error correction term or velocity entails a further interpolate of these measures of money market disequilibrium from quarterly to monthly frequency.[12]

Figure 5 plots the error correction term from our money demand model along with the deviation of (the inverse of) velocity from both a Hodrick-Prescott filter as described above and from a simple log-linear trend. As expected, the two velocity measures have a significantly higher variance than the error correction, particularly in the latter half of the period, including over the period of the global crisis. In the analysis below we report results for the error-correction term only: further work is required to assess the properties of these alternative measures of monetary disequilibrium, although re-estimating the model using the deviation of inverse velocity from its Hodrick-Prescott trend generates broadly comparable, if less statistically significant, results as reported below.

[11] The money demand equation (5) is estimated on quarterly data requiring we therefore interpolate equation (5') to a monthly frequency prior to inclusion in our inflation equations.

[12] In future work, it will be increasingly possible to use the NBS quarterly real GDP series to generate improved quarterly estimates of the demand for money and velocity.

Food Prices: domestic versus international supply factors

Low per capita incomes and high poverty in Tanzania place a large proportion of the population on or close to a subsistence existence; at such levels the consumption basket is dominated by food whose demand is highly price and income inelastic. The evolution of food prices will therefore primarily reflect variations in domestic and international supply conditions. International trade in food on either the import or export side accounts for a relatively small share of total consumption and production: there is some cross-border trade in maize and rice over the borders with DRC, Zambia and Kenya, but most food consumed is produced domestically.[13] Moreover, the topography of Tanzania means that food production is concentrated around the periphery of the country resulting in substantial internal trade in food from the surplus regions in the south and west to the deficit regions around Lake Victoria, in the centre of the country, and along the coast south of Tanga. Transport costs are therefore likely to play a central role in leveraging up the role of food prices in explaining overall inflation.

International trade and food price inflation

Though modest in aggregate, the potential for cross-border trade will nonetheless place limits on how far domestic food prices can deviate from world prices. If transport was costless and there were no other frictions, trade in food would arbitrage away *any* deviations of domestic prices from world prices. In reality, however, arbitrage will be limited by the presence of a variety of constraints on trade, the most important being high transport costs, policy barriers and monopoly power. As a result, the domestic price of food can move around within a band without triggering price-stabilizing international trade. The band within which the domestic price can move, the 'parity band', is defined by the export- and import-parity prices respectively and is given by

$$(1-c)(1-t_X)EP_F^{\$} \leq P_F \leq (1+c)(1+t_I)EP_F^{\$} \qquad (8)$$

where world food prices $P_F^{\$}$ are exogenously given in dollar terms, *c* denotes the (constant) marginal transport cost of moving good from the world to the domestic market (expressed as a proportion of the landed world prices) and where t_X and t_I are the relevant trade taxes. If Tanzania was either a consistent net food importer or exporter, the domestic price would be at the import- or export-parity price bound, respectively. At either boundary, with fixed ad valorem tariffs or taxes and constant proportional transport costs, domestic food inflation will be equal to the sum of exchange rate depreciation and world food inflation, $\pi_{Ft} = \hat{E}_t + \pi_{Ft}^{\$}$. Away from these bounds, food prices will behave like a non-traded good whose price is driven by variations in domestic supply and demand conditions.

The higher are tariffs, per-unit transport costs (as a result of higher fuel prices, for example) and other components of transport and distribution activities, the wider the bands and the more 'non-tradable' domestic food prices will be.[14] These effects may well be exacerbated in the presence of

[13] Back-of-the-envelope calculations based on National Accounts and Balance of Payment data for 2005-2008, food imports as a share of food consumption are in the order of 6%. See also Ng and Aksoy (2008)

[14] Quantitative restrictions on trade give rise to tax-equivalents on either the export or import side but when these restrictions bind prices are not stabilized by trade. Rather, the tax-equivalent adjusts endogenously to any change in domestic supply and demand conditions or in the world price without placing a limit on prices.

imperfect competition in trade and distribution as monopolists' will mark-up their prices over cost pro-cyclically with (world) food prices.[15]

To reflect this 'partial tradability' of food we model domestic food inflation as a function of both domestic supply factors, measured as shocks to yields, and international price arbitrage constraints operating directly through food prices and indirectly though fuel prices, in each case intermediated by movements in the exchange rate.[16] Which of these dominates depends not just on the evolution of domestic and external conditions but also on the degree of openness to trade in food.[17]

Real Exchange Rates and price arbitrage in food and fuel

We measure the strength of arbitrage between domestic and world markets by studying the relative price, or real exchange rate, of goods and services in domestic and world markets measured in a common currency. The simplest theory about these relative prices /real exchange rates is *relative purchasing power parity* (relative PPP), which states that when measured in a common currency, the domestic and foreign price indexes should differ from one another by a constant proportion on average. Under this hypothesis, the real exchange rate is stationary, which means that it can be expressed as the sum of a constant and a stationary variable with a mean of zero. In the case of food prices this is given as:

$$ (9) \qquad ln\left(\frac{E.P_F^W}{P_F}\right)_t = (e_t + p_{Ft}^W - p_{Ft}) = c + \varepsilon_t $$

where lower-case letters denote the log of the nominal effective exchange rate, world food prices and domestic food prices respectively. Relative PPP has the implication that whenever the real exchange rate is away from its long-run mean, at least one of its three components – the nominal exchange rate, world prices or the domestic price – must adjust over time, to bring the real exchange rate back towards *c*. Because world food prices are exogenous to developments in Tanzania, the two candidates for this error-correction behavior are the nominal effective exchange rate and the Tanzanian price level. Relative PPP says (for example) that following a period of overvaluation we would expect to observe some combination of depreciation and food price disinflation in Tanzania. A similar analysis holds for fuel prices and, in principle, for core prices.

An enforced import quota therefore ends up placing no ceiling at all on domestic food prices, while an enforced export ban imposes no floor.

[15] Assuming the monopolist faces constant marginal costs, his mark-up will be increasing in the price *in*elasticity of demand. By Engel's Law, household demand of necessities such as food is likely to be highly inelastic and increasingly so as food consumption falls towards the subsistence threshold. It follows that for a net food importing country with imperfectly competitive importers, food is likely to become less tradable – due to a rising markup over the world price – at precisely the time it is most scarce on the domestic market.
[16] Note that if food were fully tradable prices at the margin would be tied down by the import/export parity price; the characteristics of domestic demand would be irrelevant.

[17] An alternative modelling approach would be to model domestic food price inflation using a regime-switching framework (see Goldfeld and Quandt, 1973) which models the switch from between tradability (quantity-adjustment via international price arbitrage) to non-tradability (price adjustment) as a function of exogenous factors such as yield determinants, transport costs, trade policy etc.

We compute and plot the domestic food and fuel price real exchange rates for Tanzania.[18] Two features are immediately apparent from **Figures 6 and 7**. The first is that to the extent that the relative prices for food and fuel are stationary it is so only around a strongly negative trend (i.e. a real exchange rate depreciation) at least until the end of 2007. These trend declines in the relative prices of food and fuel present a challenge to our analysis. For food, the fall stands in contrast with other recent research on agricultural productivity and food prices in Tanzania which suggest stagnant or declining average total factor productivity in agriculture over the last decade which is inconsistent with sharply falling real (farm-gate) food prices (see Kirchberger and Mishili, 2011, and Lokina *et al* , 2011). One possible explanation for the trend is that the early part of the decade saw a steady trend decline in the transport cost component in domestic food prices (relative to that embodied in world food price index) leading to a depreciation of the real exchange rate for food defined in terms of consumer prices. This might reflect changes in transport technology towards more transport-efficient production, or even increased competition in the sector. A more likely explanation, as suggested in Figure 7 is that until around 2006 domestic controls on fuel prices served to slow the rise of domestic fuel prices relative to world prices. This appears to be part of the explanation but it is possible that the trend also reflects the deeper problems that have plagued the accurate measurement of output and prices in the agricultural sector and which have place a central role in recent debates concerned with understanding the relationship between growth and poverty reduction in Tanzania over the last decade (see for example, Mkenda et al (2010) and Atkinson and Lugo (2010) both of whom suggest that official prices series may have significantly understated food price inflation between the 2001 and 2007 Household Budget Surveys). We will return to this issue in Appendix II, but in the econometric analysis presented below, we side-step both the measurement controversy and the need to model the domestic price control regime by removing the trend in the food relative price to focus on a de-trended series computed by applying a Hodrick-Prescott filter to de-trend the relative prices for food and fuel. [19]

The second key feature of both the food and fuel real exchange rates is preserved in the de-trended series (overlaid on Figures 6 and 7), namely that domestic prices have frequently deviated substantially from their parity values. In the case of food prices this suggests a relatively weak link on average between domestic and world food prices consistent with an economy with limited exposure to international markets arising from high transport costs and other non-tariff barriers. In Appendix III we examine some evidence which suggest that the degree of integration between domestic and world markets in food is significantly influenced by location: the closer domestic markets are to a key cross-border trading points, such as Arusha (for Kenya) or Dar es Salaam (the world market), the more local prices react to variations in the world food prices.

Figure 8 provides a closer look at the relative price for energy by decomposing the components of the relative price for fuel for the period from late 2003 (after the end of the trend decline in

[18] The world price series are the World Bank all-food and energy price indices for low and middle-income countries respectively expressed in US dollars: there are converted to local currency using the official bilateral exchange rate with the US dollar.

[19] Loening et al (2009) follow a similar strategy in their analysis of inflation in Ethiopia.

domestic fuel prices) to show how, during the global financial crisis, exchange rate movements provided substantial relief to fuel importers. At the time that global fuel prices were rising very sharply, rising prices for Tanzania's exports, most notably gold, provided some protection against the rising dollar price of oil. Since mid-2009, however, the pass-through from world to domestic fuel prices has been much more substantial. We return to the pass through of fuel price in more detail in Section 4.

Domestic supply conditions and food price inflation

Finally in this section we turn to domestic food supply factors. As noted, a conventional approach to measuring the impact of supply variation on food prices is through direct measurement of what has been called the agricultural supply gap, defined as the deviation of actual from potential agricultural output, where the latter is defined as output under 'normal' growing conditions:

(10) $$y_t^a = yp_t^a + agap_t.$$

In principle, *agap* could be computed using standard decomposition methods such as a Hodrick-Prescott filter.[20] Doing so for agricultural output in Tanzania presents two major problems: the first is that consistent time series on agricultural output are typically not available on anything higher than annual frequency and second, there are significant discrepancies between the available annual series. The first of these problems is beginning to be addressed: since 2009 the National Bureau of Statistics has been publishing a disaggregated quarterly GDP series for Tanzania, back to 2001. This series has not yet been analyzed in detail and we remain concerned that it exhibits an implausibly large degree of seasonal variation.[21] But even so, there are major differences between the FAO's net production series and real value added in agriculture from the Tanzanian national accounts, with the latter showing almost none of the volatility of the FAO series. In particular the sharp fluctuation in output between 2002 and 2003 reported by the FAO are completely absent in the national accounts data, as is the apparent contraction in output between 2007 and 2008.[22]

Using rainfall to measure the agricultural supply gap

In order to circumvent these measurement problems, and with an eye to future 'real time' application of this model, we use instead high-frequency rainfall data as a direct proxy for the variation in agricultural supply. Food crop agriculture, particularly the production of staple foods of maize, beans and rice, is overwhelmingly rain fed so that conditional on planting decisions (i.e. on choices over land, labour and fertilizer inputs etc), yield variation is high and dependent overwhelmingly on rainfall variation. **Figure 9** illustrates the production year in Tanzania. The bulk

[20] Loening et al (2009) adopt this approach, first interpolating agricultural GDP in Ethiopia from annual to monthly frequency and applying a Hodrick-Prescott filter.

[21] This presumably reflects decisions on how the treatment of inventories and 'work-in-progress' which, in the context of highly seasonal agriculture will dominate the data series. The NBS has not yet released a detailed description of the methodology used to construct quarterly agricultural GDP.

[22] Narrative analysis from the USAID "Famine Early Warning System Network", FEWSNET, which point to bumper crops in the key growing areas in 2002 followed by poor rainfall and incipient food security problems in 2003 and 2004, appear to support the patterns reported by FAO. FEWSNET analysis also supports weak output in late 2006 and 2007.

of food production occurs in the unimodal south western regions of the country where the *msimu* rains from November through to April, roughly three months prior to the harvest, are critical.

Based on Dekadal (10-day) rainfall data collected by the Tanzania Meteorological Authority (TMA) for the 20 administrative districts of Tanzania, we compute long-run monthly average rainfall at the district level and take the current deviation of actual rainfall from this long-run average as our basic proxy for the agricultural output gap. **Figure 10** presents the long-run average monthly rainfall by district for mainland Tanzania and Zanzibar. Our empirical proxy for is defined as the deviation of actual rainfall from its long-run seasonal average for the principal unimodal growing districts, letting the lag between rainfall variation and its impact on prices be determined by the data. **Figure 11** plots a smoothed moving average of our rainfall deviation for producing regions over the sample period. As discussed below, we allow for the possibility that deviations of rainfall from the norm are asymmetric – that 'too much' rain has a stronger effect on prices than 'too little' – as well as the possibility that the effects on prices are non-linear by examining the square of the (positive or negative) deviations from the long-run mean.[23]

Storage

The final factor determining food prices is storage. Both public and private storage should dampen within-year seasonal variation in prices. Households have an incentive to hold food stocks if they expect their marginal utility of food to be higher in the future than in the present, most obviously between harvest time and the hungry season. These storage activities should dampen seasonal fluctuations in prices, although not entirely if storage is costly, because of carry costs or physical deterioration. Similar considerations mean that across-year private storage is unlikely to be as effective. We have no empirical evidence on private storage although the impact of within-season private smoothing will be absorbed by the monthly seasonal dummy variables used in our regression analysis.

Public sector storage in Tanzania is facilitated by the National Grain Reserve Authority (NGRA) whose sales and purchases can in principle be used to smooth food prices seasonally, spatially, or even across years (subject to the physical deterioration of stocks), at least when price movements lie strictly within the parity band for a given location – so that the good in question is effectively non-traded at the margin. When local market prices are arbitraged fairly continuously with world grain prices intervention by the NGRA will have no effect on price unless it is large enough to drive imports to zero. Similarly, when prices in border regions are being pushed up by pressures from neighboring countries (e.g., along the Tanzania/Kenya border in late 2009), attempts to use grain sales to lower grain prices will tend to spill abroad as increased exports, with little effect on local prices.[24]

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[23] We also computed separate measures for those districts specializing in maize, rice and beans although these were dominated by the aggregate measure.

[24] Note that when food prices play an important role in the inflation process there may be a complementarity between policies that affect the spatial or time pattern of food supplies – and that lie outside of the domain of monetary policy – and the efforts of the monetary authority to provide an effective anchor for inflation (Ndulu 1997). The policies in question might include trade policies, public grain reserve operations, or support to private storage and/or transport. If interventions that facilitate smoothing can be achieved at limited fiscal cost, they are likely to improve the overall environment for inflation control. If they become fiscally unsustainable, however, their microeconomic benefits may come at the expense of macroeconomic stability.

4. Results

Tables 2 to 5 report a range of estimates of equation (4) for monthly data on headline inflation and its sub-components for the period from January 2002 to June 2011 (a total sample of T=126, although some early observations in the sample are lost in data transformations and lags). The results presented in these tables are the outcome of an extensive search process across different dynamic specifications; we report only the most robust results here.[25] To facilitate interpretation of the results, **Table 6** reports the standardized beta coefficients corresponding to the raw coefficients in the dominant specifications from Tables 2 to 5 (indicated by the column headings). Standardized coefficients allow for an assessment of the relative contribution of variations in the individual regressors to the overall variation in inflation.[26] Table 2 reports the results for food inflation, Tables 3 and 4 the results for energy and core inflation (i.e. the non-energy component of the non-food index) and Table 5 the results for headline inflation. Each equation is estimated free of cross-equation restrictions so that lagged inflation in each sub-component can enter its own equation and those of the other sub-components.

The dependent variable in each case is the annualized value of monthly inflation defined as 1200*Δlnp_t^i for *i=(food, energy, core and headine)* and in all cases we condition the model on a set of 11 centered monthly dummy variables (*Jan…Nov*). For convenience these are not reported in the tables. We do however plot the seasonal patterns from equations [F1], [E1], [C1] and [H1] respectively in **Figure 12**. Each equation is also conditioned on three further dummy variables included to reflect un-resolved measurement concerns. Specifically, *d06m7* is an 'intercept correction' designed to pick up what appears to be a levels adjustment in the food price series which saw food prices drop by around 5% in one month; *d02m3m4* is a 'pulse dummy' to pick up an atypical movement in non-food prices at the very beginning of our sample period. In this instance non-food inflation dropped very sharply in March 2002 but spiked by the same amount in April of the same year. The final dummy variable, d10m9 controls for the introduction of a new CPI series from September 2009. This takes the form of an 'intercept correction' to the price levels for headline inflation and each of the sub-components.[27]

Goodness of fit and diagnostics The battery of diagnostic tests reported below each table suggests that the models for headline inflation and its components are suitably conditioned, so that the equation residuals are stationary and broadly white noise. There are a small number of deviations from this benchmark, most notably error non-normality in headline inflation which, in turn, reflects non-normality in energy and core inflation, both of which exhibit a small number of

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[25] It has become increasingly popular for specification searches to be automated using programmes such as PC-GETS (Hendry and Krolzig, 2007); given the short span of data at our disposal and the relatively strong priors on plausible dynamics we eschew this approach in favour of a more theory-driven specification search.

[26] Letting the raw parameters be defined by the vector $\boldsymbol{\beta} = \{\beta_1, \beta_2, \dots, \beta_k\}'$, the 'beta coefficients' are defined as $\widetilde{\boldsymbol{\beta}} = \{\beta_1\left(\frac{\sigma_{X1}}{\sigma_Y}\right), \beta_2\left(\frac{\sigma_{X2}}{\sigma_Y}\right), \dots, \beta_k\left(\frac{\sigma_{Xk}}{\sigma_Y}\right)\}'$ where σ_{Xk} and σ_Y are the sample standard deviations of regressor *k* and the dependent variable respectively.

[27] An 'intercept correction' represents a permanent shift in the *level* of the price index; with the dependent variable the change in the (log) price level, the dummy enters with a value of D=1 for the period when the shift takes place. A 'pulse' dummy on the other hand enters with a value D=1 and D=-1 picking up the increase and reversal in the growth rate.

extreme values across the sample. To the extent these are not captured in our models they are manifest in excess error kurtosis, leading to the rejection of normality. But in general the models do not exhibit generalized error autocorrelation, nor is there evidence of any heteroscedasticity, although we report heteroscedastic-consistent standard errors throughout. The overall goodness of fit of the set of models varies substantially, ranging from approximately $\bar{R}^2 = 0.68$ in the case of food inflation to only 0.15 for core inflation; for headline inflation overall, the fit is reasonably good, with an $\bar{R}^2 = 0.63$.

A substantial share of the explanatory power of the food and, as a consequence, headline inflation equations resides in the estimated seasonal pattern in inflation (conditional on controlling for other inflation determinants). F-tests against the seasonal dummies decisively reject the null of no seasonal pattern in inflation only for food and headline inflation but not for non-food and core inflation (see Figure 12). The pattern of seasonality accords with expectations. Food inflation picks up from the third quarter of each year, peaking around planting time in December and January – the 'hunger season' (see Figure 8) --and falls sharply in June and July following harvest. This pattern can be seen in overall inflation although is slightly moderated by a countervailing but statistically insignificant non-food seasonality. It is notable that, other things equal, non-food prices fall relative to their mean at the time of highest seasonal food prices consistent with a negative demand effect when food prices are at their highest, as suggested in Section 2.

Food price inflation **Table 2** presents results for the food inflation equation in which we distinguish between demand-side and supply side factors and between short-run from long-run or error-correction effects. Columns [F1] and [F2] present a basic 'symmetrical' specification while columns [F3] to [F7] explore potential asymmetries and non-linearities in the food inflation equation. Consistent with our priors, column [F1] indicates that, consistent with our priors, food inflation is driven primarily by supply-side determinants. We find a weak but statistically insignificant positive effect of excess money growth on food inflation and a direct short-run effect from the growth rate of broad money, both acting with a one-quarter lag, but these effects are substantially outweighed by supply-side factors (see Table 6 for an indication of the relative importance of each of these factors to the overall variation in food inflation). First, the negative coefficient on the error correction term on the food real exchange rate indicates price-stabilizing international trade in food: if domestic food prices rise above world prices adjusted for the exchange rate, food imports will increase augmenting domestic supply and returning domestic prices back towards their PPP value. Although this effect is statistically significant, it is relatively weak (see Table 6) and operates with a substantial lag: the error correction coefficient suggests that for the economy as a whole it takes around 5 months for this stabilizing effect to start to take effect.

Second, our rainfall-based proxy for the agricultural output gap is statistically significant and plausibly signed: other things equal, good rains (i.e. positive excess rainfall) dampen food price inflation with a lag of about one quarter (again conditional on the regular seasonal variation in prices) and *vice versa* for deficient rainfall. More precisely, the coefficient on *(r-rbar)* suggests that when rainfall is 10 percent above its seasonal mean, food inflation drops by around three quarters of one percent.

Finally, domestic food prices are influenced by deviations of domestic energy prices from their long-run relative PPP value. As we shall see in Table 3, we find a conventional error correction effect tying domestic to world energy prices. Excess domestic energy prices adjust back towards their equilibrium in a conventional manner but, as the results here indicate, for the duration of this disequilibrium there is positive spill-over onto domestic food prices, presumably reflecting the energy intensity of food production, both through the high transport cost component in domestic retail food and the cost of intermediate inputs to food production such as fertilizer.

Before leaving these basic results we note three further features. First, food price inflation displays little persistence; the positive effect from the second lag of food prices is exactly offset and neutralized by the effect at four lags. In other words there is no memory in food price inflation beyond four months, conditional on other factors including the seasonal pattern of prices.   The second feature is the significant cross effect from non-food to food price inflation (see [F1]); consistent with the previous paragraph, the evidence in [F2] shows that this is primarily as a result of energy prices.   Finally, we find that net grain purchases by the strategic grain reserves (i.e. actions to reduce aggregate food supply, *ceteris paribus*) operate in the expected direction but the measured effect on food inflation is nugatory and not statistically significant. This is consistent with the narrative evidence on the grain reserve whose net interventions appear to be determined by factors other than aggregate price stabilization.

In columns [F3] to [F7] we examine potential non-linearities and asymmetries in these supply-side effects. Column [F3] suggests there is a weak tendency for large deviations of domestic prices from their PPP value entails more rapid error correction while columns [F4] and [F7] test for differential reactions positive and negative deviations of domestic food prices from world food prices and of domestic energy prices from world energy prices. In both cases, the asymmetry is decisive; food price inflation *rises* much more rapidly when world prices exceed domestic prices than it falls when world prices are below domestic prices.   The pattern for energy prices is less dramatic but nonetheless suggests that the spillover to food prices is about twice as strong, and twice a significant in response to positive energy price shocks (i.e. when domestic energy prices exceed their PPP level) as it is to negative energy price shocks.   Finally, columns [F5], [F6] and [F7] allow for asymmetric inflation responses to positive and negative rainfall deviations and show that positive rainfall shocks have a significant (inflation-moderating) effect while negative rainfall shocks (droughts) tend to have a much weaker tendency to increase food inflation, other things equal.

Taken together, these results are consistent with much of the anecdotal evidence on the trade in stable foods in Tanzania. To see this, consider the results in [F7] and assume for convenience that domestic supply is at its equilibrium or normal value (i.e. $(r-\bar{r})=0$). In this case, the results indicate that a spike in world food prices which implies $\left(p_f-p_f^*\right)<0$, is transmitted powerfully to domestic food inflation (since the coefficient on $\left(p_f-p_f^*\right)<0$ is -0.499 the product of the variable and the coefficient is positive), whilst a decline in world food prices has a much weaker and less significant dampening effect on domestic food inflation (the coefficient is only one third as large at -0.130). In other words, adverse world conditions are transmitted to the domestic economy more powerfully than benign ones.   The results on rainfall deviations suggest a similar asymmetry with price adjustments being stronger in times of domestic surplus ($(r-\bar{r})>0$) than at times of domestic deficit. This pattern that is consistent with a trade regime in which food imports are liberalized at times of adverse domestic supply conditions so as to prevent domestic prices from rising but where there is a reluctance to allow food surpluses to be exported with the result that good supply drives down domestic prices.

If the National Grain Reserve Authority buys and sells maize to smooth prices against variations in domestic output then this will tend to dampen the food prices response to supply shocks. Therefore, controlling for net SGR maize purchases should *increase* the absolute value of the error correction coefficients on these supply-side factors; as the comparison of [F5] and [F6] shows this is indeed the case but the effect is very small and not statistically significant.

Energy price inflation The dynamics of non-food inflation are also broadly consistent with our priors. Following a similar strategy to that for food inflation, **Table 3** reports a set of results for energy prices which tell a relatively simple story. It is worth noting here that energy accounts for a relatively small share of the overall CPI (5.7%). Moreover, the domestic energy sub-aggregate covers both the tradable fuels that appear in the world energy price index, albeit with different weights and some that don't (most notably charcoal and a substantial share of hydroelectric generation).[28] The correspondence between domestic and foreign energy prices is therefore not exact. Nevertheless, the dominant feature of the energy price regressions is the extent to which domestic inflation prices are anchored to the world price index. The error correction coefficient of around -0.50 is highly significant and suggests a powerful and rapid adjust of domestic to world energy prices (see column [E1]). As with food price inflation, we observe an asymmetry: as shown in [E4], starting from equilibrium, domestic energy prices adjust (downwards) more rapidly to a fall in world energy prices than to a rise in world prices. Beyond this anchor effect, energy prices are relatively poorly explained. We can exclude any effects coming from the money market equilibrium, although there is a weak short-run effect from the growth in broad money, and we find no conventional persistence in energy inflation; as with the food price inflation, we find an 'acceleration' specification fits the dynamic data well. One small and unresolved puzzle with the energy equation is the unexpected positive feedback from food prices onto energy prices. One possible but un-tested explanation is that both prices are driven in part by rainfall, with poor rainfall having both directly increasing food prices and reducing the share of relatively cheap hydroelectric electricity generation.

Fuel price inflation: an aside In light of this concern that the composition of the energy price index is obscuring the underlying dynamics we narrow the focus of our attention to fuel prices, principally for oil, stripping out domestically generated energy sources including hydroelectric generation. In doing so, we limit our attention to the pass-through from world to domestic fuel prices for the period from 2004, in other words from the end of the sharp downward trend in domestic prices (see Figure 8). Stripping out fuel prices from the energy price index in this manner proves to be helpful as we are able to recover a well-defined error correction representation of the fuel price pass-through.

Over the period since early 2005, world fuel prices have risen by approximately 50 percent in US dollar terms, spiking in July 2008 before falling back sharply in early 2009. The domestic fuel price index followed the same pattern but with a much damped amplitude, partly because offsetting exchange rate movements served to intermediate this relationship: the appreciation of the Shilling from mid-2006 to mid-2008 moderated the rise in the domestic price of fuel during the spike in

[28] The world energy index consists of crude oil (0.846), coal (0.047) and natural gas (0.108) where the terms in brackets are the weights in the index. The weight of solid fuels (principally charcoal) in the domestic basket is

world prices. The subsequent weakening of the Shilling in 2008 and 2009, however, meant that less of the fall in world prices fed through onto domestic fuel prices. During the most recent rise in world prices, movements in the exchange rate worked in the opposite direction, exacerbating rather than protecting domestic prices from movements in the dollar price of fuels.

To examine the pass-through from world to domestic fuel prices, and the role of the exchange rate in this, we estimate a simple three-variable VECM of the form

$$\Delta X_t = \sum_{k=1}^{p} \Gamma \Delta X_{t-k} + \Pi X_{t-1} + \varepsilon_t \qquad (11)$$

where $X_t = \left(p_t^f, p_t^{f*}, e_t\right)'$ whose elements are, respectively, the (logs of) the domestic fuel price index, the world fuel price index and the Tsh/US$ nominal exchange rate, and $\Pi = \alpha\beta'$ is the reduced-rank matrix where the vector β' consists of the coefficients of the cointegrating vector(s) and α contains the corresponding feedback effects. **Table 7** reports unit root tests and Johansen's test for cointegration between the variables. The three series are I(1) in levels and stationary I(0) after first-differencing: Π therefore contains at most two cointegrating combinations. The trace statistic test rejects the null of no cointegration in favour on there being a single cointegrating relationship between the three variables. This is reported as the un-restricted cointegrating vector. Both the exchange rate and the world price are statistically significant and enter the vector with the expected sign. We impose two restrictions on the cointegrating relationship, the first that the domestic fuel price responds symmetrically to movements in the exchange rate and the world fuel price, and the second that both the world fuel price and the exchange rate are weakly exogenous with respect to the domestic fuel price, this being Johansen's (1992) test of the 'partial system' restriction that allows us to estimate the fuel price error correction equation as a single equation. The likelihood ratio test reported at the foot of the table indicates that both restrictions are comfortably accepted by the data (the p-value of LR test is 0.286).

The restricted equation implies a less-than-complete long run pass-though from the (exchange rate adjusted) world fuel price. It is likely that this reflects the very substantial deviation from equilibrium in July 2008 when the world price briefly touch US$149 per barrel but where the Tanzanian shilling was unusually appreciated and where offsetting actions were taken by the domestic authorities to cap the pass through. We expect that with a longer time series, one less dominated by this enormous spike, we would not be able to reject the null that the long run pass through is unity.

Table 8 reports the variants of the error correction equation for fuel prices around the restricted cointegrating vector. Deviations of domestic fuel prices from their long-run PPP value are adjusted quickly with around 20% of the deviation from equilibrium eliminated after one month (see column [1]). Column [2] suggests that domestic prices return to their equilibrium significantly more rapidly when domestic prices are below their equilibrium than when they are above (the p-value is 0.04). Around this error-correction effect the short-run dynamics are conventional and consistent with results elsewhere in this paper. Thus we observe modest short-run persistence in domestic fuel prices and a broadly symmetrical response to exchange rate movements.

Core inflation Finally we turn to core inflation. Although the model explains a relatively small share of the variation in core inflation, the results in **Table 4** conform to the textbook description of core inflation being determined essentially on the demand side. Monetary factors, both the deviation for money market equilibrium and in particular short-run monetary growth matter significantly for core inflation. In contrast to food and energy prices, however, we do find evidence of some stickiness in core inflation operating through the first and second lags, although in quantitative terms the implied persistence in core inflation is minimal. In addition we find that lagged food price inflation (and to a much milder extent, lagged energy inflation) exert a weak negative effect on core inflation, consistent with the transmission mechanism described in Section 2 above where rising food and fuel prices squeeze the non-food share of consumers' budgets transmitting a negative demand impulse onto core inflation.

The absence of any supply-side factors in determining core inflation is surprising, although this may be due to deficiencies in measurement. It is plausible that at least the tradable share of core prices would be tied through arbitrage to their corresponding world prices, but for the sub-aggregate as a whole we have been unable to identify a robust stationary real exchange rate relationship with conventional real effective exchange rate measures based on world price indices such as US or OECD wholesale price indices. We have also not yet succeeded in identifying a robust measure of an output gap for core inflation (beyond the implicit effect working through the money demand error correction term). Addressing these supply side issues are priority issues for future work and may go some way to improving the explanatory power of the core inflation equation.[29]

Headline inflation Pulling together the main features from the sub-components we present preferred results for headline inflation in **Table** 5. These results contain no surprises, reflecting the dominant features from the models for the principal sub-components more or less in proportion to the relative weight of each component in the consumption basket. The drivers of food price inflation, including the powerful seasonality in food prices, remain significant in the equation for headline inflation and broadly proportional to the relative weight of food in the basket, while the strong impact of excess money growth on non-food inflation also carries over. Although not reported here, the asymmetric real exchange rate and rainfall effects noted in Tables 2 and 3 remain present, although, without the same level of statistical significance. And, as can be seen in [H5], the dynamic patterns observed earlier also carry through to headline inflation: beyond the seasonal pattern, the only source of persistence in headline inflation comes from some mild stickiness in core inflation.

One final feature of these results concerns the role of the exchange rate. Once we have controlled for its effect on the pass-through from world food and fuel prices – and the role it plays in determining the equilibrium demand for money -- we find virtually no additional independent short-

[29] Neither NBS nor the Bank of Tanzania currently report monthly output indicators of non-agricultural economic activity. It is possible to construct an interpolated index of industrial production from the NBS quarterly GDP series; preliminary attempts to do so have not yet generated useful insights. . It may be possible to use these data to construct a robust output gap for core inflation. As an alternative we compute the deviation of the real effective range exchange range from its equilibrium but did not find a significant role for this variable in the core inflation equation.

run role for the nominal exchange in any of the inflation equations, except very weakly through core inflation (see [C1] and [C2]).[30]

5. Conclusions, caveats and next steps

The immediate objective of this paper has been to investigate the inflation process in Tanzania over the past decade. In this respect we have been reasonably successful: the econometric analysis offers a set of inflation equations that identify, with varying degrees of precision, a plausible characterization of the main determinants of inflation in headline prices and its principal components. A number of puzzles remain with the analysis and with the underlying data. Moreover some of the results are undeniably fragile: the statistical significance of results is not always high and it remains an open question, for example, of how robust the estimates will prove to be out of sample. Nonetheless the analysis points to a number of reasonably robust conclusions which have direct implications for policy.

First, money growth and hence the stance of monetary policy matters for inflation both in the long run and in the short run. The transmission to headline inflation is principally through core inflation but not exclusively so; monetary or demand-side effects also feed food and fuel price inflation, particularly in the short run. Second, however, the principal component of overall inflation -- food price inflation -- is predominantly driven by both domestic agricultural supply shocks, proxied by deviations of rainfall from its long-run pattern, and by the pass-through from world prices for food and fuel. Though statistically significant, the inflation transmission from world from prices is relatively weak and somewhat attenuated, although this pass through is much stronger when world prices rise than when they fall. We also find that these effects are stronger the closer domestic markets are to principal entrepôt locations such as Arusha and Dar es Salaam. Third, the effect of domestic supply conditions on food price inflation points to the asymmetric effects of trade policy in Tanzania; while food imports appear to respond reasonably rapidly to domestic production short-falls, the capacity to export surplus food production is much more muted so that market adjustment in this case occurs through falling prices, other things equal. This results appears to have important implications for trade policy and production incentives in agriculture although, as noted below, a much closer analysis of regional prices is required before firm policy conclusions can be drawn. Fourth, headline inflation exhibits strong seasonality, reflecting the within-year price dynamics in food. Non-food inflation is, by contrast, broadly non-seasonal. Finally, prices in Tanzania in general are flexible, more so for the food and energy sub-components but even in the traditionally sticky-price domain of core inflation there is little evidence of persistence. Some of the adjustments to equilibrium are somewhat prolonged, but conditional on these error-correction effects, inflationary shocks dissipate rapidly with half-live being little more than one month.

These conclusions need to be tempered by three further considerations, all of which should probably be considered in future work. First, as noted, further work is required on the supply-side and pass-through effects operating on core inflation. The overall fit of this equation is poor and the

[30] The point estimates of the exchange rate (semi-)elasticity are low; a month-to-month depreciation of the nominal exchange rate of 10 percent would increase the annualized inflation rate by around 0.5 percentage points.

absence of any arbitrage effects counterintuitive. Second, as we note in Appendix II, there is quite strong *prima facie* evidence suggesting that official price data may systematically biased downwards, especially over the first half of the decade. We control for this to some extent in our analysis but it would seem sensible both to subject our analysis to more sensitivity analysis across sub-samples and, when it comes to forecasting, to base forecasts on a shorter historical data span, possibly only from around mid-decade, after which the trend bias in prices appears to have moderated. The final priority modification concerns the definition of 'world prices'. At present, our models include measures of the deviation of domestic food and fuel prices from world price indices derived from the World Bank commodities database. This may be appropriate for fuel and energy prices, but not for food, where the relevant external price for food in Tanzania should probably be a regional rather than a world price. No such measure is readily available but could and should probably be constructed from the national data of neighbouring countries.

Beyond developing a coherent description of the contemporary inflationary process in Tanzania, the enduring value of this analysis rests on extent to which it can supports the Bank of Tanzania's capacity to forecast future inflation. Systematic inflation forecasting in Tanzania is in its infancy and is currently based on a small set of ARIMA time-series models. ARIMA models offer a valuable baseline or reference set of forecasts but by construction they do not exploit the richer information set underpinning the semi-structural models estimated in this paper. But exploiting this additional information to generate forecasts from conditional models of this form brings its own challenges. Most obviously it depends on our ability to develop a coherent projection for the vector of exogenous conditioning variables. An important component of the modeling strategy adopted in this paper has been to rely as much as possible on data that are generated at high frequency, in a timely manner and, to the extent possible, can themselves be readily forecast. Most of the variables we have used are published prior to or quite soon after the underlying price data, which are published approximately two weeks after the month end. World price data (for food and fuel), exchange rates and monetary data are all produced within or close to this window, while the TMA rainfall data follow with a short lag. Moreover, there already exist various market-based and other forecasts for world food and fuel prices over the 3-12 month forecast horizons the Bank is considering, while the Bank itself already operates a forward-looking reserve monetary programme from which broad money can be forecast. The one major exception is the money market error-correction which is derived from an underlying money demand equation estimated at a quarterly frequency. As we noted in Section 3, we may be able to approximate the money market terms by focusing on simple velocity estimates. If this is feasible, we will then have sufficient data to re-estimate the structural inflation equations on nearly real-time data, thereby providing a practical basis for forecasting. How in practice we do so, and how we address associated specific challenges in developing a framework for forecasting and forecast-evaluation defines the next stage of our research on inflation.

Appendix I: The NBS price data

Price indices collected by the National Bureau of Statistics are based on Household Budget Surveys (HBS) of which there have been five since 1969.[31] The price series used in this paper are the September 2006 revision of the CPI based on the HBS for 2001. We splice these with the new series CPI published by NBS from October 2010 and based on weights from the 2007 HBS. Price data for the new series were computed from October 2009: we use the revised rather than original data for the period from October 2009 to September 2011.

As noted, the originally-released CPI series based on 2001 HBS weights was subject to a major revision in 2006. Prompted by concerns from users that the index appeared to be systematically underestimating inflation, the IMF conducted a review of price data collection methods finding that procedures for handling 'outliers' and other technical errors in compilation were imparting a significant downward bias to the CPI. Following correction, the CPI was recomputed back to a base observation of January 2002 with the corrected series being adopted as the official CPI series.

A new CPI, based on consumption weights from the 2007 Household Budget Survey, was published in October 2010. The weights for the new CPI are based on consumption of both urban and rural consumers (in contrast to the 2001-based CPI which was urban-only). In principle, therefore, NBS could now construct regional CPIs but it was decided that data quality precluded such an option at present. Separate indices for Dar es Salaam by income level are also compiled by NBS but at present are not published. IMF Afritac (April 2010) has recommended NBS compile and disseminate these, along with separate indices for Other Urban Areas, Total Urban areas as well as a National Urban and Rural Index.

Table A1 reports the old and new weights for the CPI. In both case, the CPI basket is based solely on consumption relating to monetary expenditures: own production of food, along with imputed rent for owner-occupation of dwellings is not included in the basket. These deficiencies notwithstanding, IMF East Afritac (2010) concluded that the new CPI was broadly robust.

[31] See Kwimbere (2011) "The Impact of Food Prices on Inflation Developments in Tanzania" (mimeo, Bank of Tanzania)

Appendix II: Some concerns with the CPI

Despite the wholesale revision of the 2001 CPI, concerns about the price series remain. In an unpublished paper, World Bank economists argued that the September 2006 revisions improved 'a deficient measure' but did not fully eliminate the downward bias (World Bank, 2007). Similar concerns emerge from analyses of the measured poverty dynamics in Tanzania, much of which turns around the problems of reconciling the official CPI and National Accounts data with the implied price and output measures derived the Household Budget Surveys between 2001 and 2007 (see Mkenda et al, 2010 and Atkinson and Lugo, 2010).

We do not have the space in this paper to undertake a detailed forensic analysis of the price indices over the early 2000s. But using a sub-set of commodity-level price data obtained from NBS we conclude there appears to still be a substantial downward bias in official price series. NBS provided us with regional price data on 49 commodities for the period 2001 to 2009. These data cover all the major food and non-food components of the CPI and account forapproximately75 percent of total household consumption.

Using the 49 commodities for which we have regional price data from the NBS, we calculate food, non-food and headline price indexes by applying weights that approximate the relative importance of these commodities in the 2007 CPI. These indexes differ from the NBS price indexes in three main respects: first, as noted, they are constructed on the basis of a smaller set of items; second they use the 2007 and not 2001 weights and third, they are computed using geometric averages whereas the NBS (we believe) use arithmetic averaging for computing price indices. Finally, missing values for each commodity/region/period are interpolated using a regression of the commodity price for that region on the prices of the same commodity in other regions. It is not obvious that any of these things should make a big difference to the implied inflation rates.

Table A4 reports summary statistics for the constructed 'all region' CPI alongside the same statistics for the NBS revised CPI series. The difference in means is marked with our computed measure being almost twice as high as the NBS index. Figures A1 and A2 present the same information graphically. As well as plotting the two domestic series we also plot the world food price index for low and middle-income countries, converted to TSh in order to make a PPP comparison with the domestic food prices. What is striking is that the constructed series tracks the world food price. Indeed, while the constructed series is cointegrated with the world price – as predicted by relative PPP -- the NBS is not.

In principle we could produce the same comparison for non-food prices. We find, however, that where there are substantial missing values for price observations the interpolation underpinning the data presented in Table A4 and Figure A1 are not as robust. Nonetheless Figure A2 shows that the same phenomenon probably applies to non-food prices. The figure uses raw data rather than interpolated data to show annualized inflation rates for each commodity in each location over two 4-yearsub-periods, from end-2001 to end-2005 and from end-2005 to end-2009. Each point in the scatter plot applies to one of the 49 food or non-food commodities in our dataset in one of the 20 regions for which we have data. The vertical and horizontal lines are the average (headline) inflation rates for the two sub-periods, as reported by NBS. If there were no systematic bias in the NBS inflation rate the commodity-region observations would be uniformly distributed around the intersection; as is clear, the distribution plot is under-weight in the South-West quadrant, which, again, is consistent with a systematic bias in the official measure of price inflation.

The evidence presented here is not conclusive but it is strongly suggestive that despite the revision in 2006, there remains a downward bias in the food and overall inflation rate in Tanzania.

Appendix III: Pass-through: some spatial evidence

In Section 3 we suggested that the larger were transport costs and other impediments to trade, the weaker the price-stabilizing effects of cross-border trade in food and the more we expect food prices to be determined by domestic supply and demand factors. The results presented in the body of the paper, based on official CPI data, is suggestive of this trade-off. Here we use a spatial disaggregation of food price data test the hypothesis that the strength of the pass-through from world to domestic food prices weakens the more isolated a regional market is from world markets, taking distance from a cross-border or international trading post as a proxy for isolation.

We construct a food price index for each of Mainland Tanzania's regions using regionally disaggregated commodity price data provided by NBS and by applying weights that approximate the relative importance of these commodities in the 2007 CPI. Using these data we then estimate the following panel error correction model for the period January 2002 to December2009 for the 20 regions (indexed *i=1,…,20).*

(A1)
$$\Delta lnp_{it}^{f} = \beta_0 + \beta_{1i}\Delta lnp_{it}^{wf} + \alpha_{1i}(lnp_i^{f} - \gamma_0 - \gamma_1 lnp_i^{wf})_{t-1} + \alpha_{2i}(y^a - \hat{y}^a)_{t-p} + \sum_{s=1}^{11}\phi_s D_{it}^{s} + \varepsilon_{it}$$

where $\varepsilon_{it} \sim \mu_i + \theta_{it}$. and μ_i is a time-invariant region fixed effect. Given that we have sufficient time series on each region we estimate the model using a mean group estimator which imposes the restriction that the long-run parameters of the model are common across the cross-section while the error correction parameters (α_{1i} and α_{2i}) and the short run parameters of the model are unconstrained. The implicit assumption is that there exists a common food real exchange rate across all regions but that regions differ in the speed with which local prices adjust to eliminate deviations from PPP, with this speed serving as a measure of the degree of integration with world market. Figure A3 plot the estimated values for α_{1i} against a proxy for the degree of domestic remoteness of the district, constructed as the road-distance from the nearest import border city (Dar es Salaam and Arusha). While tentative, the results are consistent with the maintained hypothesis: the further districts are from border-trade the slower local food prices adjust to their long-run equilibrium (the absolute value of the error correction coefficient is lower).

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Figures

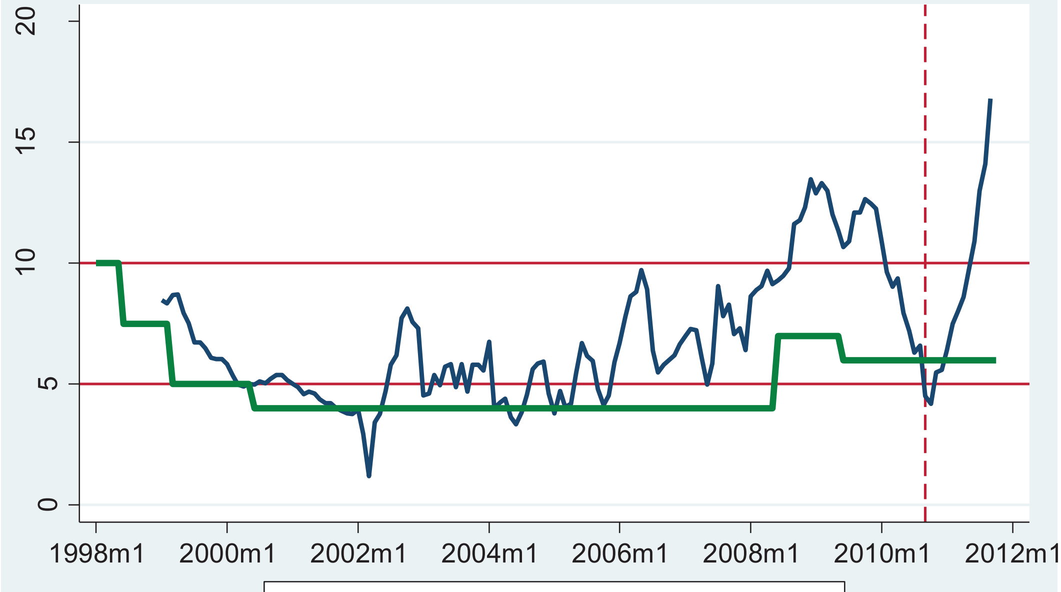

Figure 1: Annual Inflation vs Target

Source: Target established in Monetary Policy Statement in July for subsequent 12 months

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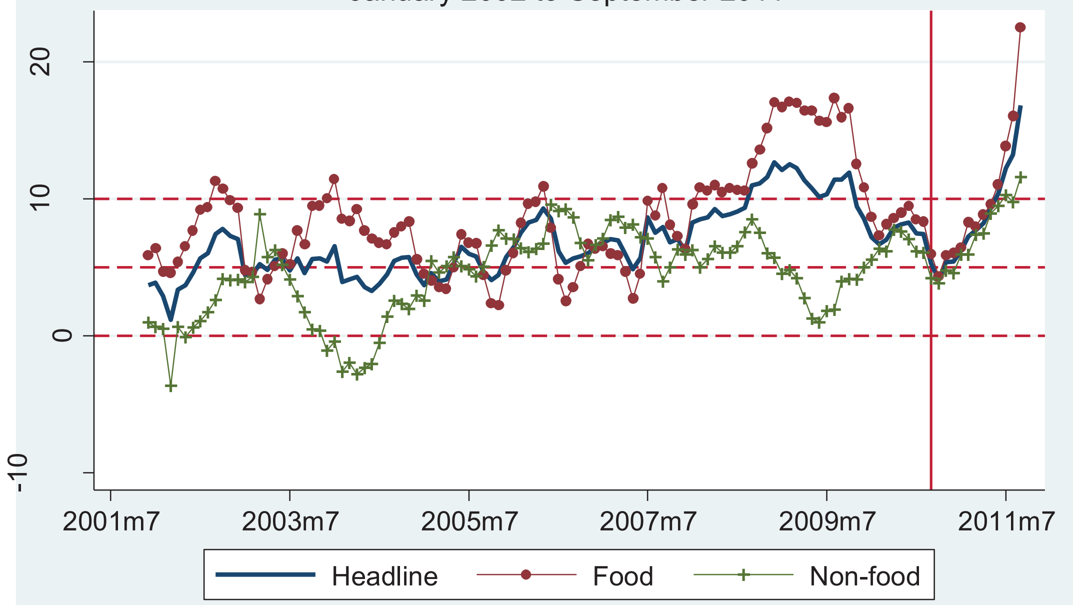

Figure 2: Inflation in revised CPI and components

January 2002 to September 2011

Source: NBS. Revised CPI from 2001m12

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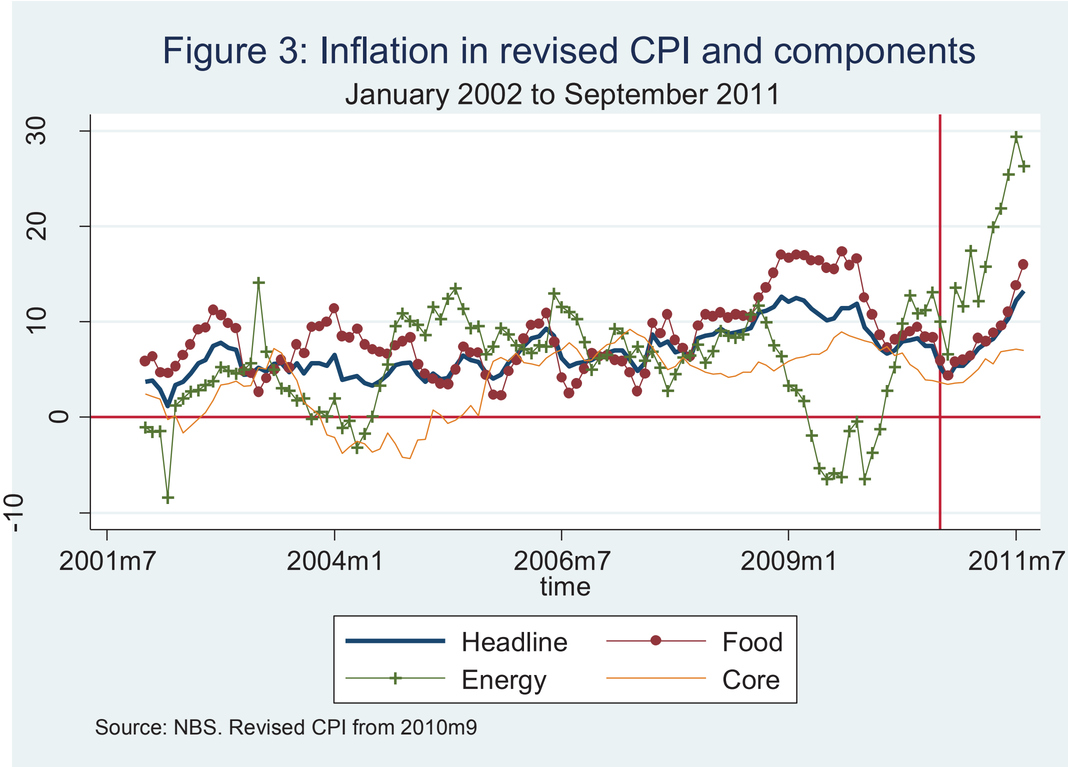

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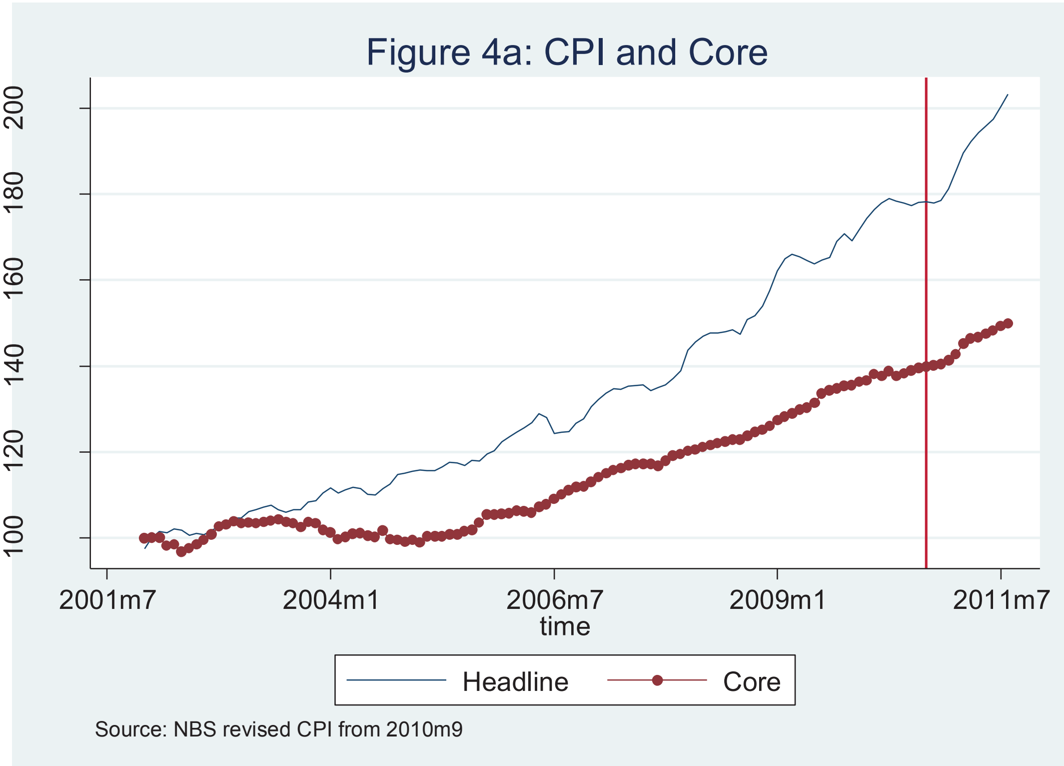

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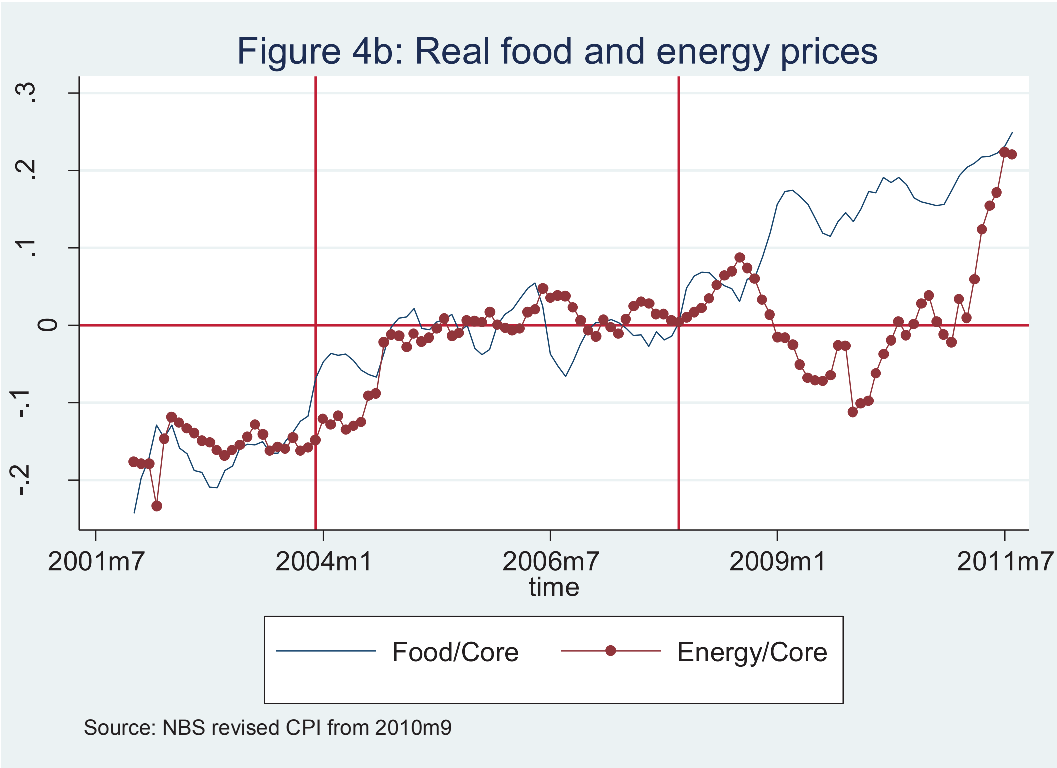

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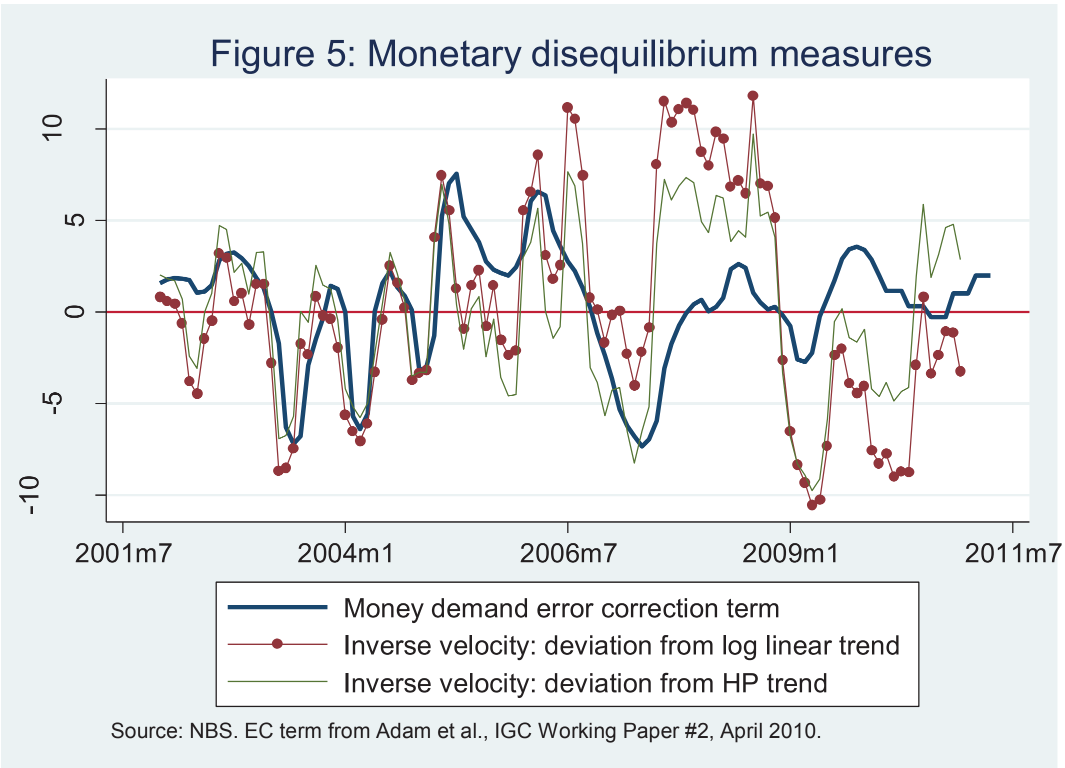

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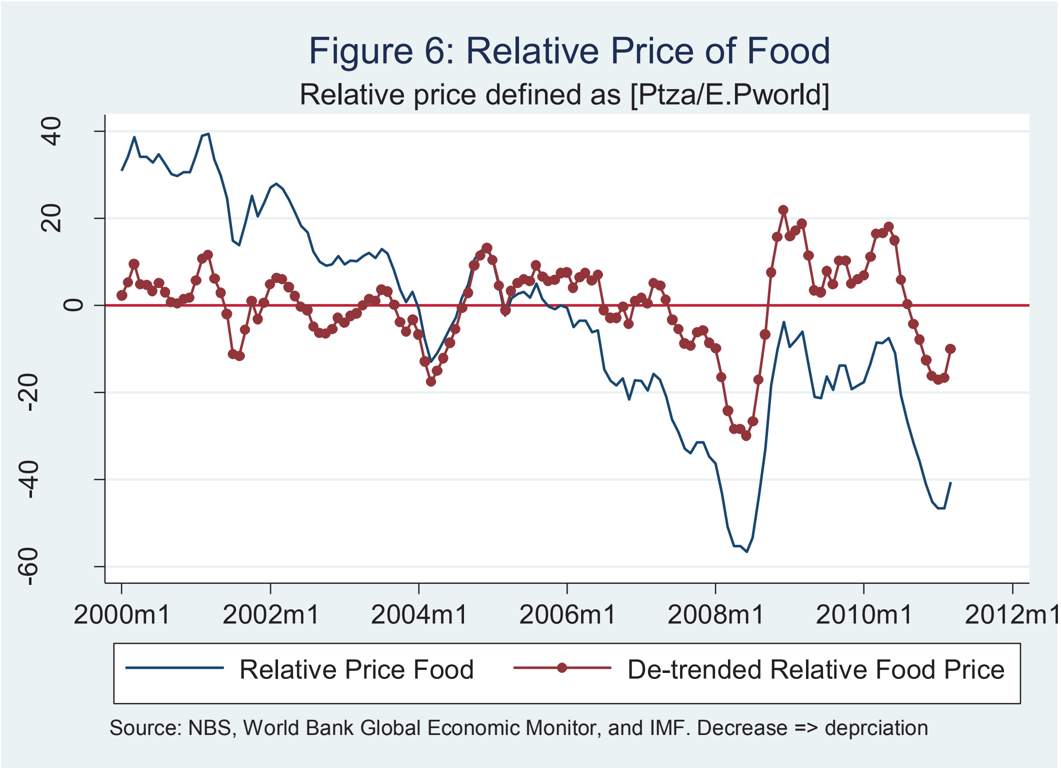

Figure 6: Relative Price of Food
Relative price defined as [Ptza/E.Pworld]

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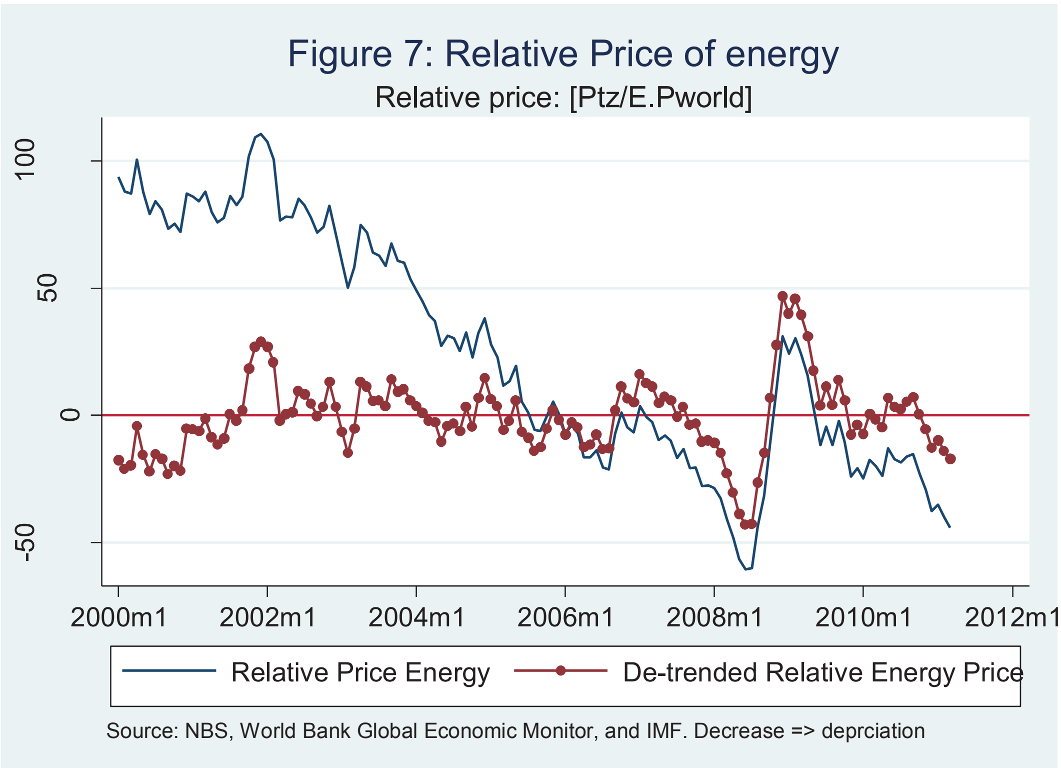

Figure 7: Relative Price of energy
Relative price: [Ptz/E.Pworld]

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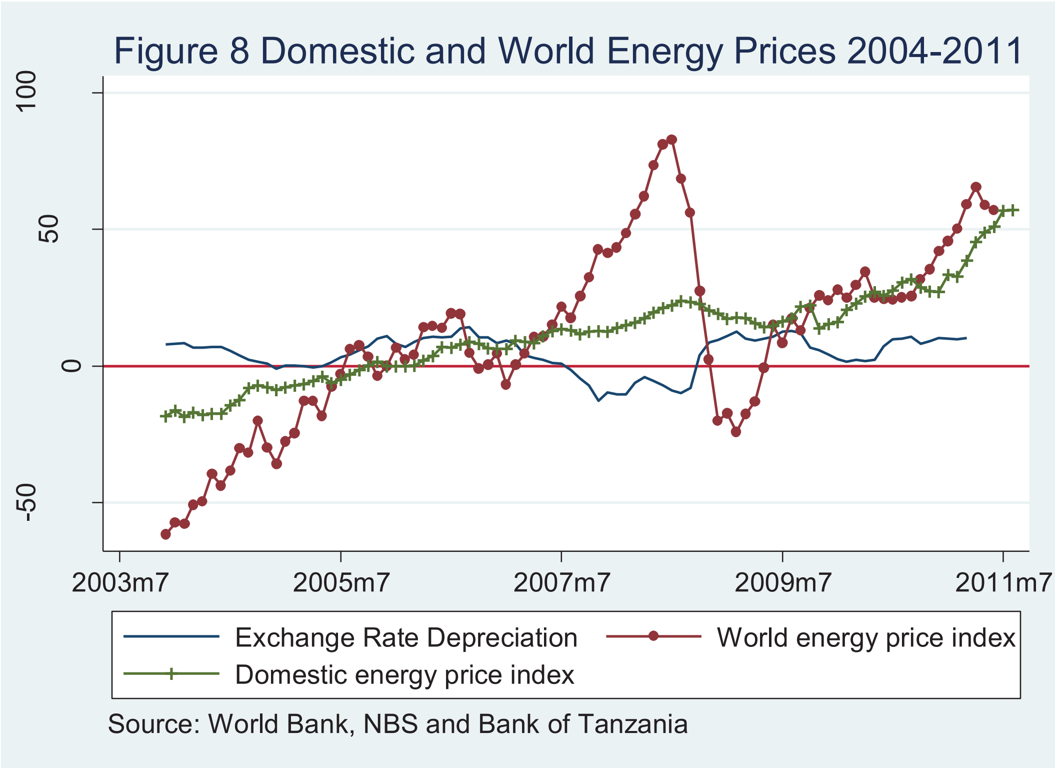

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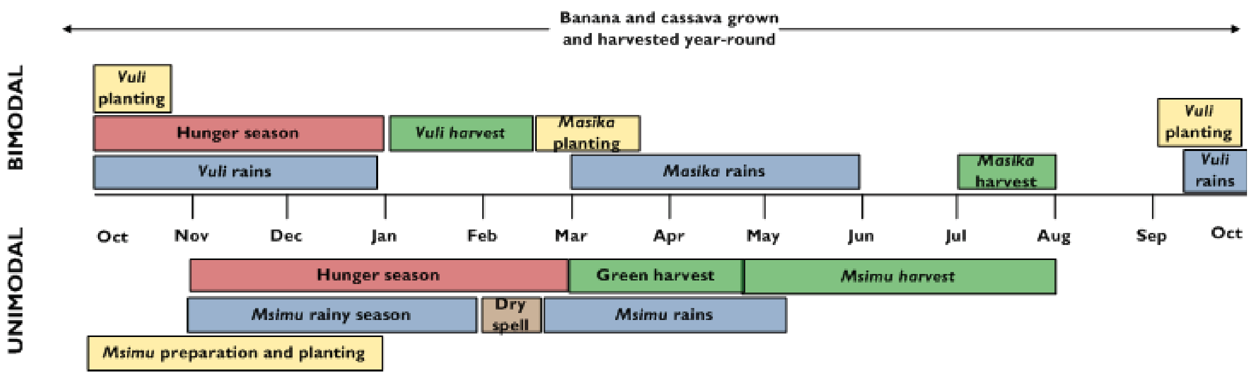
Figure 9: Tanzania rainfall and production patterns



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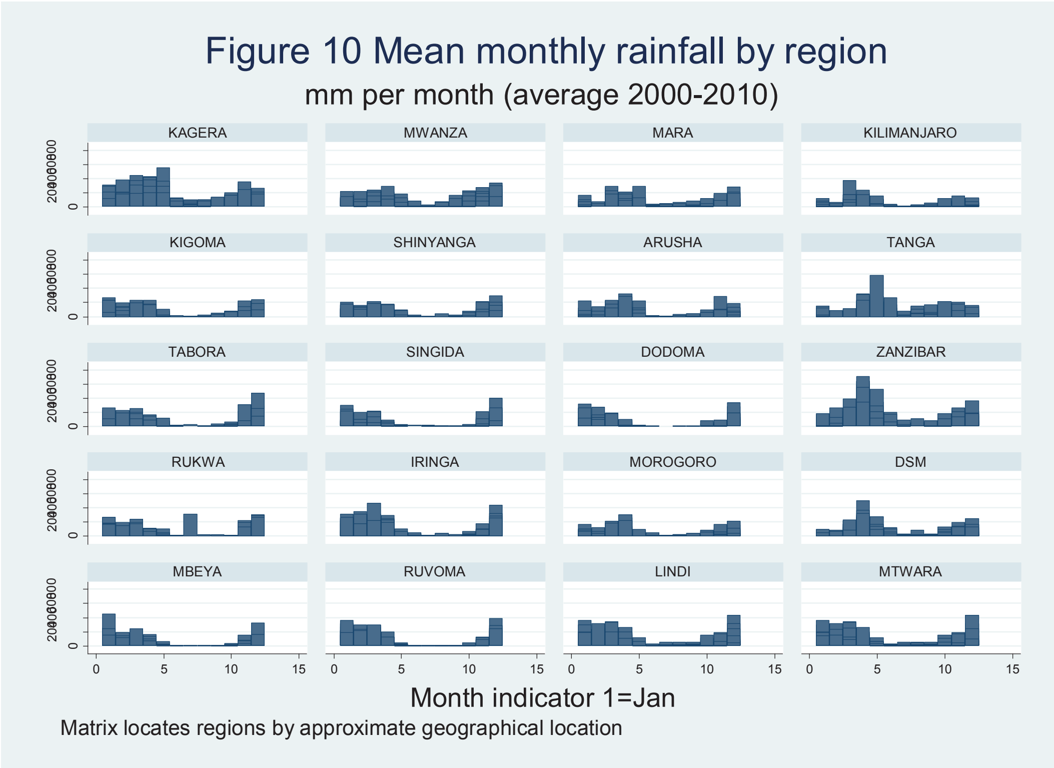

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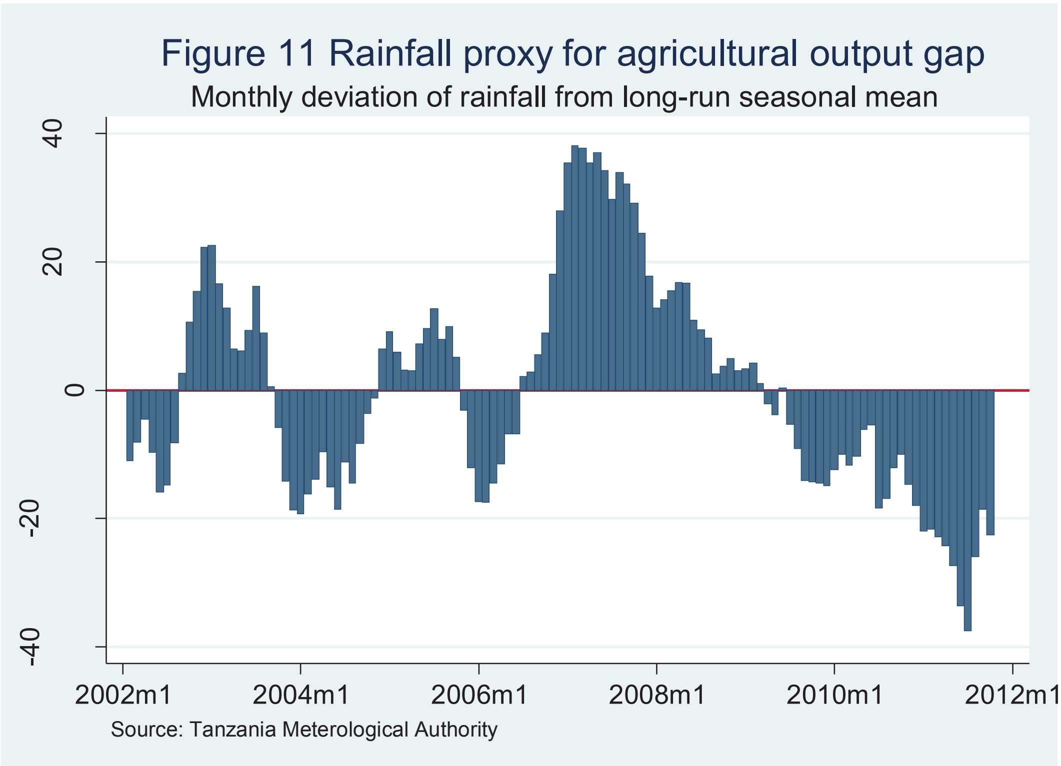

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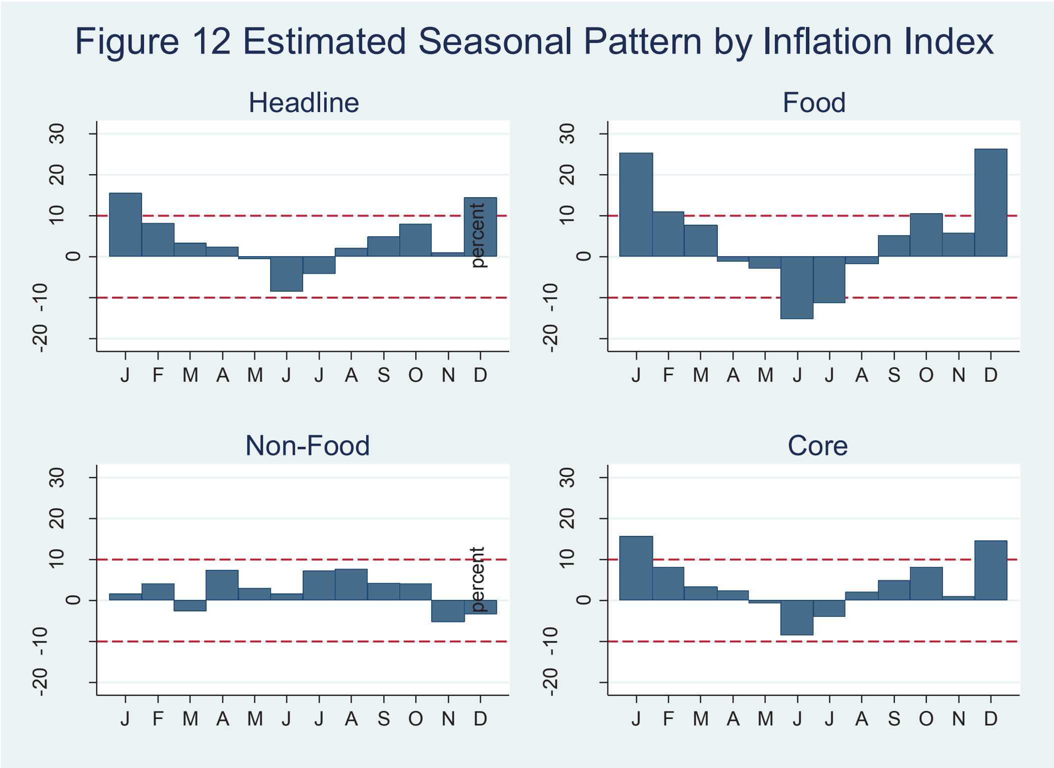

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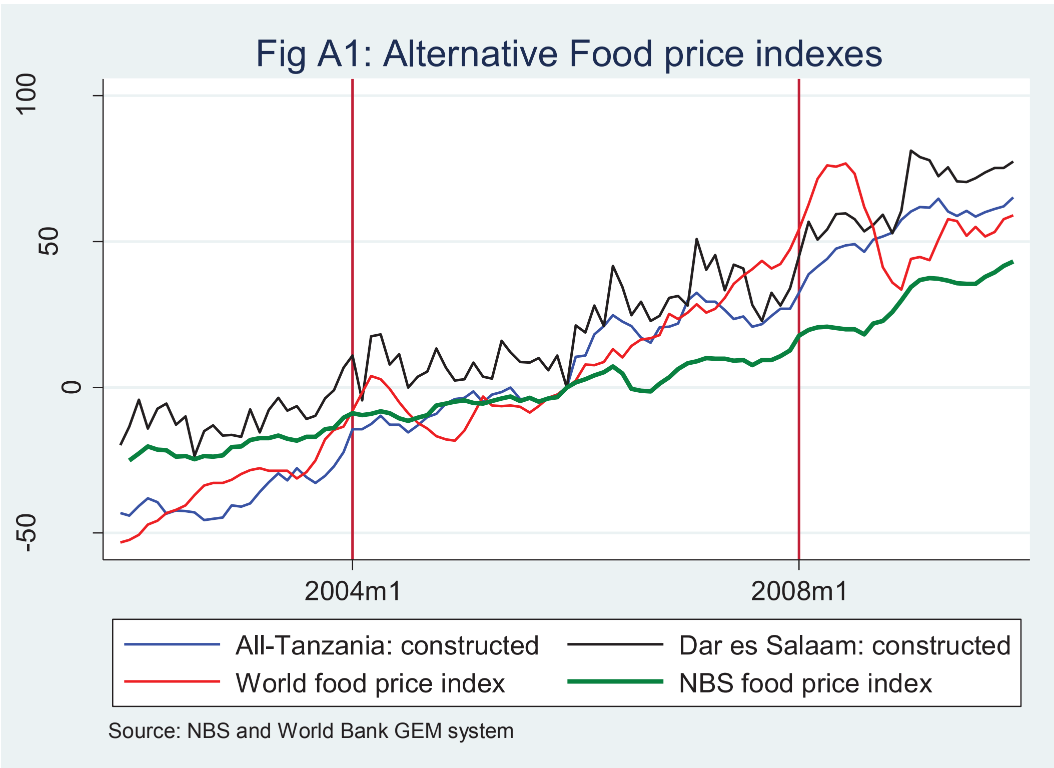

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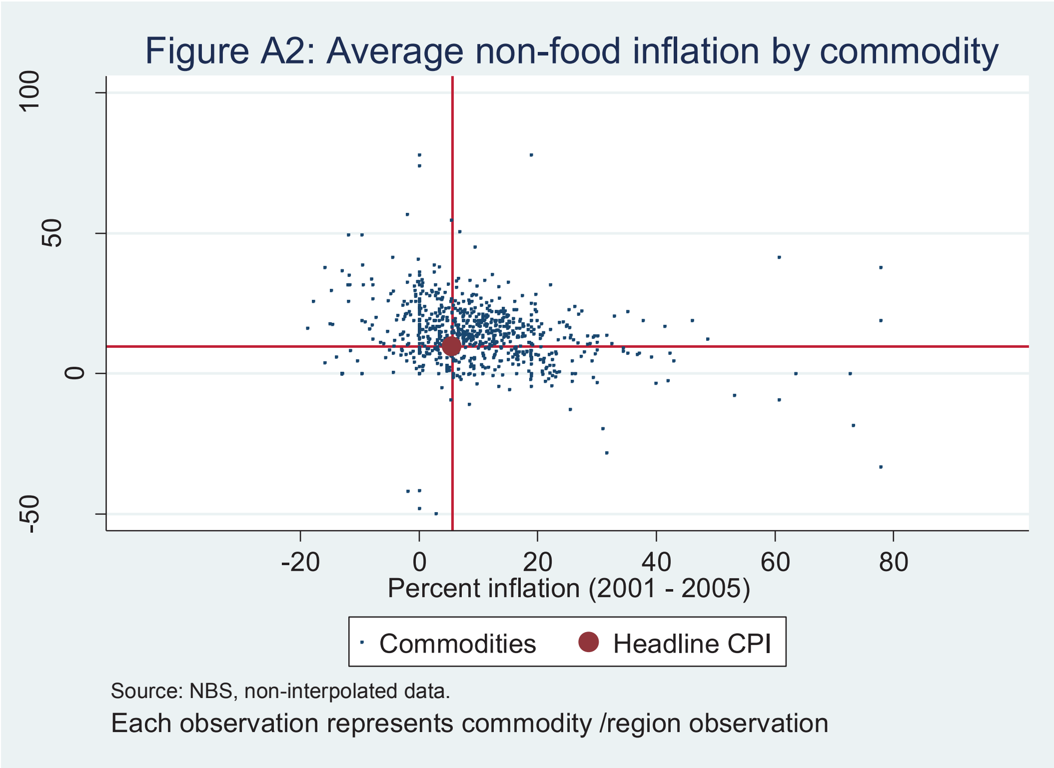

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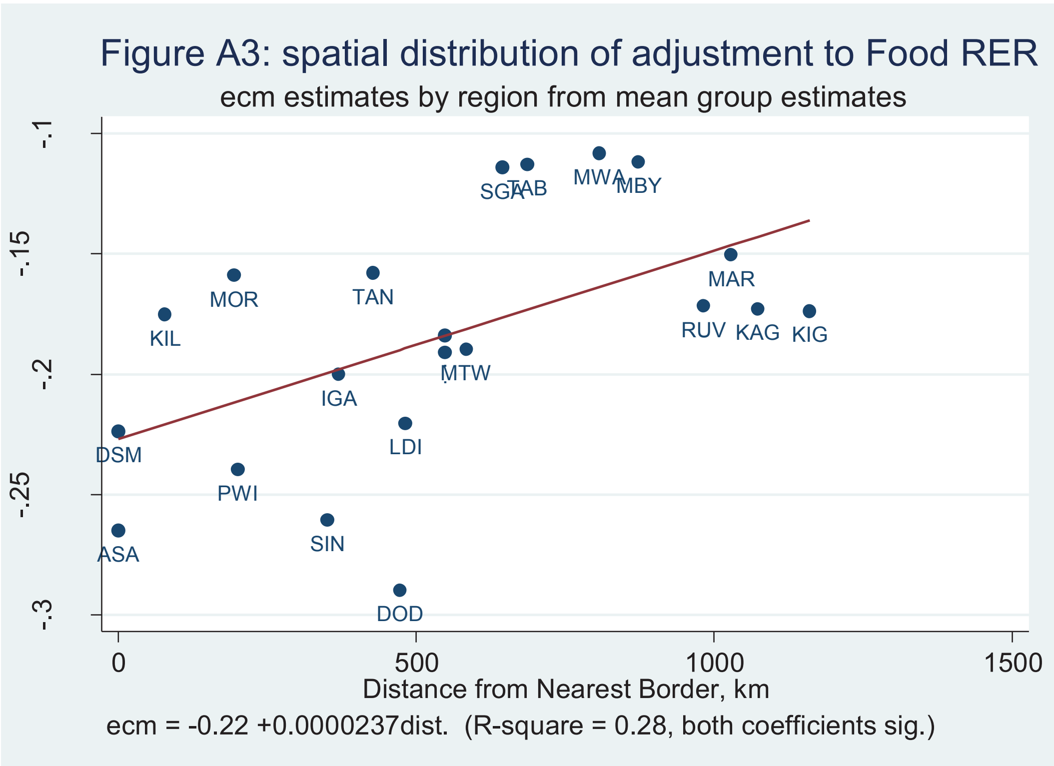

Key: Arusha (ASA); Dar es Salaam (DSM); Kilimanjaro (KIL); Morogoro (MOR); Pwani (PWI); SIN (Singida); IGA (Iringa); DOD (Dodoma); LDI (Lindi); Tanga (TAN); Mtwara (MTW); Sinyanga (SGA); Tabora (TAB); Mwanza (MWA); Mbeya (MBY); Mara (MAR); RUV (Ruvuma); Kagera (KAG); Kigoma (KIG).
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TABLE 1: Summary Statistics on Inflation

Mean inflation and standard deviations (January 2002 to June 2011) percent per annum [1].

		Mean	Std dev	Mean	Std dev	Mean	Std dev	Mean	Std dev
	Weight [2]	Unconditional full sample		Controlling for measurement adjustments[3]		Pre-Lehmans / Global Financial Crisis [Sept 2008]		Post-Lehmans [Sept 2008]	
Headline	1.000	6.96	2.53	6.19	3.16	5.84	1.87	7.01	5.00
Food	0.510	8.51	3.75	7.71	4.44	7.06	2.64	9.24	6.88
Core	0.433	3.96	3.53	3.41	3.69	2.91	3.74	4.59	3.31
Energy	0.057	6.49	6.5	4.66	5.27	5.77	4.19	2.06	6.59

Notes: [1] Inflation measured as twelve-month difference in log prices; **[2]** Weights based on new NBS series released October 2010, where food is defined as food and non-alcoholic beverages including restaurant-consumed food. **[3]** These consist of an intercept correction' to pick up an atypical movement in the food price series in July 2006; a 'pulse dummy' to pickup an atypical movement in non-food prices between March and April 2002; and an intercept correction to account for the introduction of the new CPI series from September 2009.

Source: National Bureau of Statistics

TABLE 2: Food Price Inflation

Sample: Jan 2002 to June 2011								
Dependent variable								
12*monthly food price inflation		F1	F2	F3	F4	F5	F6	F7
t-stats based on robust s.e.								
Lagged inflation								
Food inflation	(t-2)	0.217	0.203	0.212	0.214	0.213	0.193	0.216
		(3.37)	(3.08)	(3.31)	(3.13)	(3.17)	(2.89)	(3.16)
	(t-4)	-0.208	-0.201	-0.215	-0.224	-0.213	-0.206	-0.228
		(3.03)	(2.90)	(3.06)	(3.19)	(3.14)	(2.89)	(3.25)
Non-food inflation	(t-1)	0.259						
		(2.98)						
Energy inflation	(t-1)		0.118	0.133	0.135	0.110	0.105	0.123
			(2.79)	(3.14)	(3.35)	(2.73)	(2.62)	(2.98)
Core inflation	(t-3)		0.191	0.156	0.126	0.157	0.204	0.119
			(1.26)	(1.03)	(0.79)	(1.08)	(1.50)	(0.76)
Deviation from anchors								
Money								
(m-m*)	(t-3)	0.582	0.539	0.392	0.290	0.701	0.632	0.513
		(1.44)	(1.34)	(0.93)	(0.65)	(1.74)	(1.55)	(1.12)
Food								
(pf-pf*)	(t-5)	-0.413	-0.416	-0.302		-0.405	-0.420	
		(3.36)	(3.21)	(2.14)		(3.33)	(3.40)	
(pf-pf*)^2	(t-5)			-0.012				
				(1.70)				
(pf-pf*) > 0	(t-5)				0.047			-0.130
					(0.18)			(0.48)
(pf-pf*)<0	(t-5)				-0.603			-0.499
					(3.13)			(2.40)
Energy								
(pe-pe*)	(t-1)	0.237	0.242	0.219		0.263	0.269	
		(2.82)	(2.82)	(2.38)		(3.26)	(3.25)	
(pe-pe*)>0	(t-1)				0.288			0.309
					(1.96)			(2.18)
(pe-pe*)<0	(t-1)				0.123			0.158
					(0.69)			(0.90)
Rainfall								
(r-rbar)	(t-2)	-0.074	-0.069	-0.067	-0.064			
		(2.73)	(2.52)	(2.52)	(2.41)			
(r-rbar)>0	(t-2)					-0.191	-0.176	-0.164
						(3.96)	(3.57)	(2.94)
(r-rbar)<0	(t-2)					0.033	0.025	0.016
						(0.61)	(0.48)	(0.27)
Short-run factors								
Growth log M2	(t-3)	0.121	0.095	0.104	0.115	0.116	0.093	0.126
		(2.03)	(1.53)	(1.68)	(1.84)	(1.90)	(1.61)	(2.02)
Net SGR purchases								
L3.	(t-3)	0.006	0.004	0.005	0.005	0.006		0.006
		(1.46)	(1.00)	(1.18)	(1.20)	(1.55)		(1.56)
Dummy variables								
d06m7		-58.070	-57.646	-56.229	-55.429	-56.193	-61.162	-55.156
		(9.40)	(9.55)	(9.37)	(9.06)	(10.02)	(14.05)	(9.45)
d02m3m4		6.926	8.346	6.984	5.896	9.992	11.021	7.858
		(1.65)	(1.96)	(1.73)	(1.32)	(2.31)	(2.73)	(1.74)
d10m9		-20.291	-17.727	-21.488	-22.292	-9.509	-10.085	-13.895
		(3.01)	(2.59)	(2.94)	(3.07)	(1.17)	(1.29)	(1.50)
constant		4.941	5.329	4.097	1.872	8.579	8.751	5.694
		(2.81)	(3.27)	(2.38)	(0.78)	(4.09)	(4.15)	(1.66)
N		119	119	119	119	119	119	119
r2		0.74	0.74	0.75	0.75	0.76	0.75	0.76
Adj - Rsq		0.67	0.68	0.68	0.68	0.69	0.69	0.69
Diagnostics								
J-B Normality		0.28	0.34	0.28	0.28	0.27	0.36	0.28
LM 1		0.93	0.80	0.96	0.92	0.93	0.82	0.82
LM 4		0.67	0.22	0.20	0.22	0.42	0.42	0.36
ARCH 1		0.46	0.43	0.44	0.61	0.36	0.49	0.51
ARCH4		0.25	0.34	0.36	0.32	0.19	0.22	0.19
BP Hettest		0.20	0.14	0.13	0.20	0.11	0.13	0.16
F-seasonal		0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: [1] t-statistics based on heteroscedastic consistent standard errors; [2] Δx denotes x(t)-x(t-1), $\Delta 2x$ = x(t)-x(t-2); [3] AR[x] denotes LM test of zero autocorrelation at lag 1 to x; ARCH[x] denotes LM test of zero autoregressive conditional heteroscedasticity of lag 1 to x; BP-HETTEST denotes Breusch-Pagan test of absence of heteroscedasticity; SK-TEST test the null for error normality. [4] All regression include 11 centred seasonal dummy variables (coefficients not reported above). F-SEASONAL denotes F-test against joint significance of seasonals. See Figure 12.

TABLE 3: Energy price inflation

Sample: Jan 2002 to June 2011

Dependent variable 12*monthly food price inflation t-stats based on robust s.e.		**E1**	**E2**	**E3**	**E4**
Lagged inflation					
Energy inflation	(t-1)	0.096			
		(1.08)			
	(t-4)	-0.104			
		(1.39)			
	Δ3(t-1)		0.100	0.103	0.109
			(1.88)	(1.94)	(2.03)
Food inflation	(t-1)	0.181	0.185		
		(1.60)	(1.62)		
	(t-3)	0.150	0.150		
		(1.33)	(1.33)		
	(t-4)				
	Σ(t-1)+(t-3)			0.173	0.200
				(2.31)	(2.39)
Deviation from anchors					
Money					
(m-m*)	(t-4)	0.161			
		(0.28)			
Energy					
(pe-pe*)	(t-1)	-0.507	-0.513	-0.520	
		(3.38)	(3.75)	(3.84)	
(pe-pe*)>0	(t-1)				-0.696
					(3.33)
(pe-pe*)<0	(t-1)				-0.332
					(1.45)
Short-run factors					
Growth log M2					
	Δ2(t-2)	1.124	1.097	1.134	1.132
		(1.64)	(1.62)	(1.65)	(1.66)
Exchange rate depreciation	(t-1)			0.069	0.068
				(0.75)	(0.75)
Dummy variables					
d06m7		-22.433	-21.467	-22.988	-23.589
		(2.88)	(3.46)	(4.16)	(4.66)
d02m3m4		-95.993	-96.171	-96.615	-95.003
		(16.26)	(16.95)	(18.27)	(18.10)
d10m9		-23.179	-23.004	-22.596	-24.176
		(2.30)	(2.41)	(2.29)	(2.46)
constant		0.783	0.861	0.266	1.797
		0.23	0.27	0.08	0.47
N	N	120	120	120	120
r2	ll	0.47	0.47	0.47	0.48
Adj - Rsq	aic	0.36	0.37	0.37	0.37
Diagnostics					
J-B Normality		0.00	0.00	0.00	0.00
LM 1		0.97	0.97	0.99	0.83
LM 4		0.81	0.83	0.73	0.92
ARCH 1		0.44	0.45	0.45	0.38
ARCH4		0.00	0.00	0.00	0.00
BP Hettest		0.02	0.02	0.03	0.03
F-seasonal		0.50	0.48	0.47	0.42

Notes: [See Table 2]

TABLE 4: Core inflation

Sample: Jan 2002 to June 2011

Dependent variable t-stats based on robust s.e.		C1	C2	C3	C4
Lagged inflation					
Core inflation	Σ(t-1)+(t-2)	0.190	0.188	0.190	0.189
		(2.69)	(2.65)	(2.71)	(3.26)
Food inflation					
	Δ2(t-2)	-0.074	-0.072	-0.077	-0.077
		(2.16)	(2.05)	(2.25)	(1.98)
Energy inflation	(t-1)				-0.028
					(0.86)
	(t-3)				-0.043
					(1.29)
Deviation from anchors					
Money					
(m-m*)	(t-4)	0.335		0.356	0.452
		(1.59)		(1.68)	(1.98)
(m-m*)>0	(t-4)		0.178		
			(0.43)		
(m-m*)<0	(t-4)		0.466		
			(1.22)		
Short-run factors					
Growth log M2	Δ2(t-1)	0.884	0.890	0.699	0.768
		(2.25)	(2.27)	(1.99)	(2.19)
Exchange rate depreciation	(t-2)	0.054	0.053		
		(1.34)	(1.30)		
Dummy variables					
d06m7		3.226	3.769	3.885	4.796
		(1.09)	(1.18)	(1.32)	(0.57)
d02m3m4		-15.784	-15.830	-16.454	-14.723
		(2.86)	(2.85)	(3.11)	(2.47)
d10m9		5.007	4.585	6.587	7.005
		(1.17)	(0.98)	(1.40)	(0.846)
constant		-0.991	-0.653	-0.081	0.031
		(0.57)	(0.30)	(0.05)	(0.1527)
N		120	120	120	120
r2		0.29	0.29	0.28	0.31
Adj - Rsq		0.16	0.15	0.15	0.15
Diagnostics					
J-B Normality		0.01	0.00	0.01	0.01
LM 1		0.37	0.37	0.40	0.51
LM 4		0.78	0.78	0.70	0.66
ARCH 1		0.40	0.45	0.32	0.36
ARCH4		0.72	0.74	0.72	0.73
BP Hettest		0.08	0.09	0.07	0.04
F-seasonal		0.53	0.55	0.53	0.51

Notes: [See Table 2a]

TABLE 5: Headline inflation

Sample: Jan 2002 to June 2011

Dependent variable 12*monthly food price inflation t-stats based on robust s.e.		**H1**	**H2**	**H3**
Lagged inflation				
Headline inflation	Δ2(t-2)	0.183		
		(2.86)		
Food inflation	Δ2(t-2)		0.107	0.105
			(2.58)	(2.55)
Energy inflation	Δ3(t-1)		0.074	0.075
			(3.22)	(3.30)
Core inflation	(t-2)		0.229	0.241
			(2.45)	(2.62)
Deviation from anchors				
Money				
(m-m*)	(t-3)	0.601	0.491	0.489
		(2.25)	(1.94)	(1.93)
Food				
(pf-pf*)	(t-5)	-0.273	-0.271	-0.273
		(3.22)	(3.32)	(3.36)
Energy				
(pe-pe*)	(t-1)	0.055	0.056	0.058
		(0.92)	(1.00)	(1.02)
Rainfall				
(r-rbar)	(t-2)	-0.039	-0.039	-0.038
		(2.03)	(2.16)	(2.11)
Short-run factors				
Lagged money growth	Δ(t-3)	0.038	0.020	
		(1.32)	(0.71)	
Dummy variables				
d06m7		-34.477	-39.210	-40.232
		(3.83)	(4.55)	(4.75)
d02m3m4		-10.619	-13.392	-12.172
		(1.64)	(2.16)	(2.05)
d10m9		-7.679	-10.878	-9.825
		(0.82)	(1.21)	(1.11)
constant		6.766	5.906	5.857
		(8.73)	(7.28)	(7.26)
N		119	119	119
r2		0.65	0.69	0.69
Adj - Rsq		0.58	0.62	0.63
Diagnostics				
J-B Normality		0.06	0.04	0.04
LM 1		0.04	0.46	0.48
LM 4		0.25	0.74	0.73
ARCH 1		0.82	0.67	0.74
ARCH4		0.78	0.45	0.47
BP Hettest		0.95	0.81	0.86
F-seasonal		0.00	0.00	0.00

Notes: [See Table 2]

TABLE 6: Beta coefficients
Beta Coefficients

Sample: Jan 2002 to June 2011

		F2	F5	F6	F7	E3	E4	C1	C4	H1	H3
Dependent variable		Food				Energy		Core		Headline	
12*monthly price inflation	Weight	0.51				0.057		0.433		1.00	
Lagged inflation											
Headline inflation	Δ2(t-2)									0.23 ***	
Food inflation	(t-2)	0.20 ***	0.21 ***	0.19 ***	0.22 ***						
	(t-4)	-0.20 ***	-0.22 ***	-0.21 ***	-0.23 ***						
	Δ2(t-2)							-0.22 **	-0.23 **		0.20 ***
	Σ(t-1)+(t-3)					0.17 **	0.20 **				
Energy inflation	(t-1)	0.14 ***	0.13 ***	0.12 ***	0.15 ***	0.14 *	0.15 **		-0.08		
	(t-3)								-0.12 *		
	Δ3(t-1)										0.20 ***
Core inflation	(t-2)										0.15 ***
	(t-3)	0.22	0.18	0.23 *	0.14						
	Σ(t-1)+(t-2)							0.30 **	0.29 **		
Deviation from anchors											
Money											
(m-m*)	(t-3)	0.08 *	0.10 *	0.09 *	0.08 *					0.14 **	0.12 **
	(t-5)							0.13 *	0.17 **		
Food											
(pf-pf*)	(t-5)	-0.21 ***	-0.20 ***	-0.21 ***						-0.22 ***	-0.22 ***
(pf-pf*) > 0	(t-5)				-0.03						
(pf-pf*)<0	(t-5)				-0.16 **						
Energy											
(pe-pe*)	(t-1)	0.17 ***	0.19 ***	0.19 ***		-0.32 ***				0.06	0.07
(pe-pe*)>0	(t-1)				0.14 **		-0.27 ***				
(pe-pe*)<0	(t-1)				0.07		-0.12				
Rainfall											
(r-rbar)	(t-2)	-0.14 ***								-0.13 **	-0.12 **
(r-rbar)>0	(t-2)		-0.21 ***	-0.19 ***	-0.18 ***						
(r-rbar)<0	(t-2)		0.04	0.03	0.02						
Short-run factors											
Growth log M2	(t-3)	0.10	0.12 *	0.09 *	0.13 **					0.09 *	
	Δ2(t-2)					0.12 *	0.12 *	0.27 **	0.24 **		
Net SGR purchases	(t-3)	0.07	0.09 *		0.09 *						
lagged ER depreciation	(t-1)					0.05	0.05				
	(t-2)							0.13 *			

Notes: [1] Beta coefficients defined as betaβ(i)=β(i)(σx/σy) where β(i) is the estimated coefficient from Tables 2-5, σy is the standard deviation of the dependent variable and σx the standard deviation of regressor i.
[2] *, ** , *** denote 10%, 5% and 1% significance levels respectively

TABLE 7: Fuel Price Cointegration Analysis

Sample: Dec 2004 to July 2011

Phillips-Perron Unit Root tests (Ho = unit root)		p-value of unit root tests	
		trend	no trend
Nominal exchange rate	e(t)	0.5352	0.8981
	Δe(t)	0.0000	0.0000
World fuel price	pf*(t)	0.1724 *	0.6859
	Δpf*(t)	0.0000	0.0000
Domestic fuel price	pf(t)	0.4770	0.6286
	Δpf(t)	0.0000	0.0000

Max rank	LL	eigenvalue	trace	5% cv	1% cv
0	-698.35		48.853*	29.68	35.65
1	-681.11	0.3154	14.371	15.41	20.04
2	-674.1	0.1428	0.3491	3.76	6.65
3	-673.93	0.0038			

Rank = 1

Unrestricted cointegrating vector pf(t) = 0.660pf*(t)+0.624e(t)+c+u(t)

Restricted cointegrating vector pf(t) = 0.64[pf*(t)+e(t)]+c +u(t)

LR test on weak exogeneity of restricted cointegrating vector [p=0.286]

Note: * denotes significant at 5%

TABLE A6: Fuel Price Error Correction Model

Sample: Dec 2004 to July 2011

Dependent variable 12*monthly energy and fuel price inflation t-stats based on robust s.e.	Variable	[1]	[2]
Lagged fuel inflation	t-1	0.1738	0.1775
		(1.98)	(2.05)
Lagged ER depreciation	t-1	0.2693	
		(1.72)	
	t-2	0.3544	
		(2.33)	
Lagged world fuel	t-1	0.0657	0.0337
price inflation		(1.78)	(0.74)
Error correction	ecmr		
(p-p*)	t-1	-0.2177	
		(5.57)	
Positive	ecmpos		
(p-p*)>0	t-1		-0.1873
			(2.99)
	ecmneg		
Negative	t-1		-0.2991
(p-p*)<0			(4.72)
ER Depreciation			
(positive)	t-2		0.3841
			(2.72)
(negative)	t-2		0.3036
			(2.08)
Constant		-0.0126	-0.4255
		(0.05)	(1.21)
N		78	77
r2		0.69	0.69
Adj - Rsq		0.67	0.65
Diagnostics			
J-B Normality		0.08	
LM 1		0.53	
LM 4		0.09	
ARCH 1		0.92	
ARCH4		0.40	
BP Hettest		0.89	
Symmetry F-tests			
ECM (t-1)			0.04
Exchange rate (t-1)			0.75

Table A1: CPI Consumption Weights

HBS 2001 Category	Weight	HBS 2007 Category	Weight
Food	0.559	Food and non-alcoholic beverages	0.478
Drinks and Tobacco	0.069	Alcoholic bevarages and tobacco	0.033
Clothing and Footwear	0.064	Clothing and Footwear	0.067
Rents	0.014	Housing, water, electricity, gas and other fuel	0.092
Fuel Power and Water	0.085		
Furniture and household equipment	0.021	Furniture, housing equipment and maintenance	0.067
Household maintenance	0.021		
Personal care and health	0.021	Health	0.009
Recreation and entertainment	0.008	Recreation and culture	0.013
Transportation	0.097	Transport	0.095
Education	0.026	Education	0.017
		Communication	0.021
		Restaurants and hotels	0.064
Miscellaneous goods and services	0.015	Miscellaneous goods and services	0.044
TOTAL	1.000		1.000

Table A2: Phillips- Perron Unit Root Tests
Sample: Jan 2002 to June 2011

	p-values (Ho: x(t) contains a unit root)	
Variable	**[No trend in DGP]**	
	Levels	**First difference**
Prices		
lph	0.991	0.000
lpn	0.998	0.000
lpf	0.982	0.000
lpe	0.994	0.000
lpc	0.999	0.000
Error Correction Terms		
ecm2d	0.014	0.000
ecm2dpos	0.011	0.000
ecm2dneg	0.004	0.000
lrerf_hpc	0.023	0.000
lrerfpos	0.009	0.000
lrerfneg	0.025	0.000
lrere_hpc	0.009	0.000
lrerepos	0.003	0.000
lrereneg	0.020	0.000
anomun	0.000	0.000
anomunpos	0.000	0.000
anomunneg	0.000	0.000
Other regressors		
lm2	0.937	0.000
lsgr	0.042	0.000
leu	0.413	0.000
lpwfuel	0.792	0.000
lpfuel	0.477	0.000

Notes: 'first difference' => t-(t-1) monthly difference.
See Table A3 for definitions of variables

Table A3: Variable definitions and transformations

Variable	Definition	Source
lph	log headline price index	NBS
lpf	log food price index	NBS
dlpn	log non-food price index	NBS
lpe	log energy price index	NBS
lpc	log core price index	NBS
leu	log nominal exchange rate index	BOT
lpfuel	log fuel price index	NBS
lm2	log money M2	BOT
lsgr	log net sales from Strategic Grain Reserve	BOT
lpwf	log world food price index	World Bank Commodity Price Data (Pink Sheet) from World Bank online Global Economic Monitoring database.
lpwe	log world energy price index	
lpwfuel	log world fuel price index	
Error correction terms		
ecm2d	Money (M2) market equilibrium	Adam et al (2010)
lrerf_hpc	log real exchange rate for food (lpf-leu-lpwf)	See text
lrere_hpc	log real exchange rate for energy (lpe-leu-lpwe)	See text
anomun	deviation of rainfall from seasonal mean in production regions	Tanzania Meterological Agency

TABLE A4: Food Price Inflation, December 2001 to December 2009

	Average	Std. Deviation
NBS Official food Index	8.64	4.22
All Tanzania food index (constructed)	14.66	8.16
DSM food index (constructed)	12.42	11.37
World food index (World Bank)	13.37	16.32

Note: average year-on-year change in log of price indices
Source: NBS index and raw data

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